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BIG HORN AND RELATED CEPHALOPODS

AUG. F. FOERSTE

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CONTENTS

NEW GENERA

During late Ordovician times an American Arctic fauna invaded the western part of North America, reaching as far south as El Paso, in western Texas, and Bromide, in southcentral Oklahoma.

The most northern area from which this fauna is known is at Cape Calhoun, on the northern margin of Kane Basin, on the northwestern shore of Greenland (*1*). Here it occurs in the upper

part of the Cape Calhoun series of strata. In the southern part of Baffin Island (*2*) it occurs in an area extending from Putnam Highland, east of the northern part of Foxe Land, southeastward past Nettilling Lake, to the head of Frobisher Bay, an area ranging from 950 miles to 1200 miles almost directly south of Cape Calhoun. A similar fauna is known from the area southwest of Hudson Bay (*3*), in the northeastern part of the province of Manitoba, about 800 miles southwest of the Putnam Highland. Here the occurrence of this fauna in the Nelson limestone is suggested by the presence of *Cyrtogomphoceras nutatum.* The overlying *Shamattawa limestone,* with its inclusion of *Apsidoceras boreale,* may be of Richmond age

In the southern half of Lake Winnipeg, and the adjacent part of the Red River area, between 400 and 500 miles southwest of Hudson Bay, this fauna occurs in the Red River formation (*4*). This formation includes, in descending order, the Selkirk limestone, 130 feet thick; the Cat Head limestone, 70 feet thick; and the Dog Head limestone, also 70 feet thick; or a total of 270 feet. Possibly the Winnipeg sandstone, immediately beneath the Dog Head limestone, and at least 100 feet thick, may be the basal part of the Red River formation, but there is no faunal evidence, known at present, to warrant such an inclusion. Here, representatives of the Arctic fauna occur both in the Dog Head and in the Selkirk limestones, those in the Dog Head being *Charactocerina plicata, Wilsonoceras* sp., *Lambeoceras* cf. *princeps, Digenuoceras* (*Oxygonioceras*) *latum, Westonoceras manitobense, Diestoceras whiteavesi, Cyrtogomphoceras whiteavesi,* and *Cyrtogomphoceras* cf. *turgidum,* while those of the Selkirk limestone are *Charactocerina* aff. *plicata, Wilsonoceras mccharlesi, Lambeoceras lambi, Diestoceras nobile, Cyrtogomphoceras* magnum, and *Cyrtogomphoceras whiteavesi.*

About 775 miles southwest of the southern end of Lake Winnipeg, 8 miles west of Lander, Wyoming, and a little west of the center of that state, a large cephalopod fauna belonging to this Arctic invasion has been described recently by A. K. Miller (*5*). Here it occurs in the basal (Lander) sandstone of the Big Horn formation, where this sandstone is about 5 feet thick. A few

cephalopods, apparently belonging to the same Arctic invasion, were found by T. E. Savage at Medicine Mountain, near the northern end of the Big Horn range, in Wyoming. A typical specimen of *Wilsonoceras,* resembling one of those described by A. K. Miller from the Lander area, was found by Edwin Kirk in Teton Creek canyon, in eastern Idaho, northeast of Driggs.

About 365 miles southeast of Lander, Wyoming, near Canyon City, Colorado, south of the central part of that state, cephalopods have been found in the lower part of the Fremont formation as described by Walcott (*6*). The basal part of the Fremont at the Harding quarry, about 10 feet thick, including the fauna listed from no. 3 of Walcott's section, includes also the cephalopods *Fayettoceras canyonense* and *Charactoceras canyonense* described here. These cephalopods have been identified also from the lower Fremont at Eight Mile Mountain, at the latter place associated with *Cyrtogomphoceras contractum,* the latter species belonging to a genus known at present only from the Arctic invasion.

Near Bromide, Oklahoma, about 550 miles southeast of Canyon City, Colorado, and also southeast of the center of Oklahoma, a typical specimen of *Westonoceras* (*W. deckeri*) was found by Charles E. Decker (*7*) near the top of the Viola formation, a short distance beneath strata there identified as Fernvale.

The localities here mentioned by no means exhaust those at which representatives occur of that Arctic fauna which invaded western America during the late Ordovician. However, they include the more important ones and also those from which cephalopods are described in the present paper. It by no means follows that all of these occurrences are of the same relative age. There may have been more than one invasion. Consecutive invasions from the same sea, at no great intervals of time geologically, are likely to present fossils of similar facies.

For instance, both the Dog Head and the Selkirk limestone, though separated by the Cat Head limestone, present cephalopod faunas having Arctic relationships. But the attempt to correlate the fauna of the Lander sandstone, in the basal part of the Big

Horn formation, with that of the Dog Head member of the Red River formation, and the upper part of the Big Horn with the Selkirk member of the Red River formation meets with the difficulty that a typical Arctic cephalopod fauna occurs not only in the Dog Head but also in the Selkirk member of the Red River formation, while, at present at least, this Arctic cephalopod fauna is not known from the upper part of the Big Horn formation.

It is obvious that every occurrence of cephalopods belonging to genera regarded as characteristic of Arctic invasions in areas adjoining the latter, farther eastward, will arouse considerable interest. One of the areas at present receiving attention from G. Marshall Kay (*8*), and others, is that exposing the Stewartville formation, in southern Minnesota, eastern Iowa, and northwestern Illinois. From this formation, in Minnesota, John M. Clarke (*9*) described two species under the names *Tripteroceras lambi* (Whiteaves) and *Oncoceras minnesotense* Clarke, names later changed to *Lambeoceras confertum* Foerste and *Westonoceras minnesotense* (Clarke). Both of these species, of supposedly Arctic relationship, have been found by Kay (*10*) recently at Kendallville, Iowa, 35 miles southeast of Stewartville, and also on Roberts Creek, 7 miles north of Elkador, Iowa, which lies 50 miles southeast of Kendallville, and also 50 miles northwest of Dubuque. Previously, a specimen of *Lambeoceras confertum* had been found by Edwin Kirk west of Scales Mound, Illinois, 20 miles east of Dubuque.

Judging from the literature, the Stewartville forms the basal part of the Dubuque as defined originally by Sardeson (*11*). It is the lower part of the *Maclurea bed*, as discussed by E. O. Ulrich in his correlation of the Ordovician strata of Minnesota, published in 1897 in the Geology of Minnesota (*12*). Here he stated that "The fossils occur chiefly in the lower half (of the Maclurea bed), and consist almost exclusively of large Gasteropoda, of which *Maclurea crassa*, *Maclurina cuneata*, *Maclurina manitobensis*, and *Lophospira augustina* are sometimes abundant and always characteristic." No distinguishing name has been given to that part of the Dubuque which overlies the Stewartville and contains

Pseudolingula iowensis (Owen) and *Oxoplecia ulrichi*. In the area here discussed the Dubuque is overlaid directly by the Maquoketa.

The occurrence of *Lambeoceras confertum* in the Stewartville at various localities in Minnesota, Iowa, and northwestern Illinois is of special interest since one of the specimens found in the basal sandstone of the Big Horn formation in the area west of Lander, Wyoming, can not be distinguished from this species. Moreover, another specimen of *Lambeoceras* from the Stewartville of Jo Daviess county in northwestern Illinois can not be distinguished from typical *Lambeoceras cultratum* of the basal sandstone of the Big Horn. These occurrences suggest that the Stewartville formation of the upper Mississippi Valley is approximately of the same relative age as the basal part of the Big Horn formation.

In the same manner, the apparent occurrence of *Paractinoceras canadense* in the basal sandstone of the Big Horn in the area west of Lander, Wyoming, and in the lower part of the Big Horn formation at Medicine Mountain in northern Wyoming, as well as in the Dog Head member of the Red River formation of southern Manitoba, suggests that these two horizons are approximately of the same age. Moreover, another specimen from Medicine Mountain is identified as *Ephippiorthoceras dowlingi* Foerste (*13*), a species known also from the Shammattawa limestone of the area southwest of Hudson Bay.

The danger of correlation by means of generic resemblances alone is illustrated by the vertical range of *Charactoceras* which was described originally from the Richmond of Ohio and Indiana, and is known also from the Richmond of Anticosti, the Maquoketa of Iowa, and the Fernvale of the Bromide area in Oklahoma, but which occurs also in the Cape Calhoun formation of northwestern Greenland and in the basal part of the Fremont formation in central Colorado.

In a similar manner, *Lambeoceras* and *Billingsites*, known from the basal sandstone of the Big Horn formation of central Wyoming, occur also in the basal part of the Whitewater member of the Richmond group in Ohio and Indiana, *Billingsites* occurring in the Richmond also at various localities ranging from Iowa to

Anticosti. *Westonoceras,* another genus present in the basal sandstone of the Big Horn formation, apparently is represented by the species originally described by Meek as *Orthoceras ortoni* from the middle or Southgate member of the Eden formation in the vicinity of Cincinnati, Ohio.

In the vicinity of Bromide, Oklahoma, a species of *Cryptolithus* (*14*) occurs in the Viola formation, a short distance below the horizon containing *Westonoceras,* the Viola being overlaid directly by the Fernvale formation. Kirk has recorded *Cryptolithus* (*15*) as abundant in the Eureka district of southwestern Colorado and in the Marathon Basin of southwestern Texas. He states that "In the former area the *Cryptolithus* zone overlies an horizon either of Big Horn age or younger. In the Marathon Basin it occurs in a series of limestones carrying a fauna of post-lower Bighorn age, and at the base of this series is a conglomerate carrying fossils of lower Bighorn age. This line of evidence alone strongly suggests that the lower Bighorn fauna is of pre-Maysville age. It does not dispose, however, of the possible correlation of the horizon with the Trenton." In the Bromide area *Cryptolithus* has a considerable vertical range in the Viola formation, being especially abundant in its middle part.

The present paper is concerned chiefly with a study of some of the cephalopods occurring in the basal sandstone (Lander sandstone) of the Big Horn formation of the area west of Lander, Wyoming, thus supplementing the very able report by A. K. Miller on the cephalopods of the same area and horizon. The following notes on the stratigraphical and geographical distribution of this sandstone are contributed, at my request, by Edwin Kirk.

BASAL SANDSTONE OF THE BIG HORN FORMATION

EDWIN KIRK

In the Bighorn Mountain region the Bighorn formation consists of 300 feet or more of dolomites, with some shaly beds in the uppermost portion. The lower 125 feet of the Bighorn is a massive cliff-forming dolomite. In favorable sections a thin sand-

stone is found at the extreme base of the Bighorn from which a large fauna has been collected. So far as known the fauna of this basal sandstone is the same as that of the 125-foot dolomite overlying it. The apparent paucity of faunas from the dolomite itself is due to the practical impossibility of collecting the fossils, owing to the steepness of most exposures, though they often are seen on the face of the cliff. In some places the basal sandstone may be seen intergrading with the overlying dolomite, and at times an appreciable amount of sand may be found in the lower 10 to 15 feet of the dolomite. There can be little question that the sandstone merely is the initial deposit of the Bighorn and is of the same age as the overlying dolomite.

The sandstone ranges from 1 to 5 feet in thickness. It has been seen as far north as Tensleep Creek on the western side of the Bighorn Mountains, about 60 miles south of the northern margin of Wyoming, and probably extends farther north. Southward it has been followed to the south end of the Bighorn Mountains and westward, along the Owl Creek Range, as far as Wind River Canyon. The major collections from the sandstone have been made in the Wind River Range about 8 miles west of Lander, Wyoming, along the North Fork of Popoagie Creek. There are very extensive exposures of the sandstone in this region. The sandstone undoubtedly extends westward of the Wind River canyon. The most western outcrop of the sandstone known is on the western slope of the Teton Range, along Teton Creek, just over the state line, in Idaho.

FAUNAL LISTS

The following is a list of the species described by A. K. Miller from the basal (Lander) sandstone of the Big Horn formation west of Lander. Species discussed also in the present report are starred.

Endoceras nelsonense Foerste and Savage
Endoceras fulgur (Billings)
Endoceras angustum Miller
Endoceras curvilineatum Miller
Endoceras expansissimum Miller
Endoceras giganteum Miller
Endoceras magnum Miller
Endoceras paliforme Miller
Endoceras problematicum Miller
Endoceras windriverense Miller
Cyclendoceras abundum Miller

Cyclendoceras costelliferum Miller
Cyclendoceras cyclindricum Miller
Cyclendoceras depressum Miller
Cyclendoceras expansum Miller
Cyclendoceras longum Miller
Cyclendoceras popoagiense Miller
Billingsites bellicinctus Miller
*Billingsites multicameratus Miller
Orthoceras (?) sp.
Kionoceras largum Miller
*Kionoceras paucicostatum Miller
Spyroceras olorus (Hall)
Spyroceras hastiformum Miller
Spyroceras wyomingense Miller
Charactoceras (?) costatulum Miller
Charactoceras (?) washakiense Miller
*Wilsonoceras bighornense Miller
Wilsonoceras squawcreekense Miller
Wilsonoceras sp.
Actinoceras enterprisense Miller
*Paractinoceras canadense (Whiteaves)
Kochoceras magnicameratum Miller
Kochoceras subcirculare Miller
Kochoceras subellipticum Miller
Kochoceras sublentiforme Miller
Allumettoceras subequilaterale Miller
Allumettoceras (?) sp.
*Lambeoceras cultratum Miller
Lambeoceras peculiare Miller
Lambeoceras (?) sp.
*Beloitoceras plebium (Hall)
*Beloitoceras breviposticum Miller
Beloitoceras subrectum Miller
*Wetherbyoceras contractum Miller
Diestoceras flexisutile Miller
*Diestoceras landerense Miller
*Diestoceras prolatum Miller
Dowlingoceras ornatum Miller
*Cyrtogomphoceras rotundum Miller
Cyrtogomphoceras (?) angustisiphonatum Miller

In the same publication Miller described also *Spyroceras rarum* Miller, from near the top of the massive dolomite member of the Big Horn formation on the southeastern side of Baldwin Creek, which is another branch of the Popo Agie River in the area west of Lander, Wyoming but north of Squaw Creek.

In the present publication the generic term *Charactocerina* has been proposed for a group of species which will include *Charactoceras*? *costatulum* Miller and *Charactoceras*? *washakiense* Miller. *Diestoceras landerense* Miller is used as the genotype of the new genus *Landeroceras.* The generic term *Neumatoceras* is proposed for a group of species which will include also *Beloitoceras breviposticum* Miller and *Beloitoceras subrectum* Miller. *Wetherbyoceras*? *contractum* Miller is referred to the genus *Whitfieldoceras,* proposed by Foerste in 1932–33. *Dowlingoceras ornatum* Miller appears to belong to *Diestoceras,* resembling such species as *Diestoceras fremontense* Foerste, *D. kirki* Foerste, and *D. walcotti* Foerste, described in the present report.

In the List of Species described in the present publication, those whose names are not followed by some designation of the

locality from which they were obtained, within brackets, were obtained on the south side of the Middle Fork of Popo Agie River, about 10 miles west of Lander in Wyoming.

The specimens described here as *Charactocerina kirki* and *Neumatoceras* sp. were obtained by Kirk in the basal sandstone of the Big Horn formation on the east side of the Big Horn Range, on Bear Trap Creek, between the headwaters of Beaver creek and the nearest part of the North Fork of Powder River.

Farther northward, on the west side of the Big Horn Range, on Medicine Mountain, Wyoming, about 13 miles south of the Montana state line, the following species were collected by T. E. Savage in the basal part of the Big Horn limestone, the basal sandstone not being present here: *Billingsites* cf. *multicameratus* Miller, *Digenuoceras* cf. *latum* Foerste, *Ephippiorthoceras dowlingi* Foerste and Savage, *Neumatoceras gibberosum* Foerste, *Neumatoceras nutans* Foerste, *Paractinoceras canadense* (Whitfield), and *Spyroceras rarum* Miller.

Medicine Mountain is about 200 miles almost directly west of Deadwood, in western South Dakota. In its vicinity occur the typical exposures of the Whitewood formation, consisting of a series of limestones attaining a thickness of 60 to 80 feet. From this formation the following species were identified by C. D. Walcott: *Buthotrephis* cf. *succulens*, *Receptaculites* cf. *oweni*, *Halysites gracilis*, *Dalmanella testudinaria*, *Maclurina manitobensis*, *Hormotoma* cf. *major*, and *Cyclendoceras annulatum*. The species here identified as *Cyclendoceras annulatum* probably belongs to one of the new species described by A. K. Miller. The fauna listed suggests the lower part of the Big Horn formation as known from Wyoming. As to its relationship to the Red River formation of southern Manitoba this Whitewood fauna could belong as readily to its upper or Selkirk member as to the lower or Doghead member, as far as the species here listed are concerned.

The most western exposure of the basal sandstone of the Big Horn formation known at present occurs on the eastern margin of Idaho, in the Teton Creek canyon, west of the Teton Range. Here a specimen of *Wilsonoceras* was found by Kirk which is not distinguishable from *Wilsonoceras bighornense* Miller.

At the Harding quarry, about one mile northwest of the state penitentiary at Canyon City, Colorado, the Harding sandstone, of Black River age, is overlaid by the Fremont formation. The lower part of the Fremont formation (*16*) consists of a siliceous magnesian limestone, 3 to 5 feet thick, colored red by ferruginous material. This basal part contains *Echinosphaerites*, on which account it is correlated with the Kimmswick (*17*). Here C. D. Walcott collected in 1892 the species of cephalopods described here under the names: *Charactoceras canyonense* Foerste, *Diestoceras occidentale* Foerste, *Diestoceras walcotti* Foerste, *Fayettoceras canyonense* Foerste, and *Nanno walcotti* Foerste.

The basal Fremont is exposed also along Eight Mile Mountain, on the north side of the road leading from Canyon City to Parkdale, Colorado. Here the following cephalopods were discovered by S. W. Loper in 1891: *Charactoceras canyonense* Foerste, *Cyrtogomphoceras contractum* Foerste, *Fayettoceras canyonense* Foerste, *Fremontoceras loperi* Foerste, *Neumatoceras canyonense* Foerste, *Neumatoceras* sp., and *Richardsonoceras* (?) *subcuneatum* Foerste.

Westonoceras deckeri Foerste was found by Charles E. Decker about 5 miles northwest of Bromide, Oklahoma, near the top of the Viola formation. *Deckeroceras adaense* Foerste was found by him in the Fernvale formation, immediately above the Viola, 7 miles southwest of Ada, Oklahoma. The same species occurs in the upper Elgin beds of the Maquoketa formation in Winnishiek county, Iowa.

Lambeoceras confertum Foerste and *Lambeoceras cultratum* A. K. Miller occur in the Stewartville formation of Jo Daviess county, in the northwestern corner of Illinois.

Centrocyrtoceras rotundum Foerste, *Probillingsites milleri* Foerste, and *Whitfieldoceras minimum* Foerste occur in the vicinity of Elkador, in Winnishiek county, Iowa.

The difficulty of correlating the basal part of the Big Horn formation of Wyoming definitely with one of the three members of the Red River formation of southern Manitoba, merely on the basis of generic resemblances, is indicated by the following list of some of the more significant cephalopods found in the Manitoba

formation. In this list the letters D, and S indicate presence in the Doghead and Selkirk members of the Red River formation, there being no significant species in the middle or Cathead member.

Billingsites costatulus (Whiteaves)	D
Cycloceras selkirkense (Whiteaves)	S
Digenuoceras latum Foerste	D
Charactocerina plicata (Whiteaves)	D, S
Metaplectoceras (Discoceras) canadense (Whiteaves)	D
Paractinoceras canadense (Whiteaves)	D
Lambeoceras lambii (Whiteaves)	S
Westonoceras manitobense (Whiteaves)	D
Winnipegoceras laticurvatum (Whiteaves)	D
Diestoceras nobile (Whiteaves)	S
Diestoceras whiteavesi Foerste	D
Diestoceras gibbosum Foerste	S
Cyrtogomphoceras magnum (Whiteaves)	S
Cyrtogomphoceras whiteavesi Foerste	D
Wilsonoceras mccharlesi (Whiteaves)	S
Wilsonoceras insigne (Whiteaves)	St. M.

The species here named last is from the Stony Mountain formation, the sequence in ascending order being Doghead, Cathead, Selkirk, Stony Mountain, the one named last being undoubtedly of Richmond age.

In this list the species *Digenuoceras latum*, *Paractinoceras canadense*, and *Winnipegoceras laticurvatum* suggest from actual identity of species that the basal part of the Big Horn formation corresponds to the lower or Doghead member of the Red River formation. There is no corresponding identity between any of the species occurring in the basal part of the Big Horn formation and the upper or Selkirk member of the Red River formation in Southern Manitoba. However, such species as *Charactocerina plicata*, *Lambeoceras lambii*, *Diestoceras nobile*, *Diestoceras gibbosum*, *Cyrtogomphoceras magnum*, and *Wilsonoceras mccharlesi* are sufficiently near others found in the basal part of the Big Horn formation in Wyoming to indicate that they invaded from the same sea. Moreover, they are sufficiently different from anything known at present from the upper part of the typical Big Horn formation in Wyoming to suggest that the upper part of

the Big Horn formation is not to be correlated with the upper or Selkirk member of southern Manitoba.

Attention is called to the occurrence of typical *Wilsonoceras insigne* (Whiteaves) in the still later Stony Mountain formation, evidently of Richmond age. *Billingsites*, *Lambeoceras*, and *Diestoceras* also continue into the Richmond, and *Charactoceras*, another Richmond genus, may be regarded as a derivative of *Charactocerina*.

ACKNOWLEDGMENTS

The cephalopods described here from the basal part of the Big Horn formation in the Popo Agie River area of west central Wyoming were collected by Edwin Kirk in 1924, and were long ago submitted by him to the present writer for study. However, the generically similar cephalopods from the Red River formation of southern Manitoba, being preserved in limestone, offered more opportunity of securing definite knowledge of the structure of their interiors, and therefore were preferred for the erection of new genera. In the mean time a very important paper, covering most of this Popo Agie cephalopod fauna, was published by A. K. Miller. However, as so frequently happens when two individuals collect from the same horizon and localities, the collections available to Miller do not include all of the species collected by Kirk. Advantage is taken of this fact to offer the following supplementary report.

Moreover, in recent years G. Marshall Kay has been very active in the study of the Trenton and related faunas of the upper Mississippi Valley, and A. K. Miller, owing to his connection with the University of Iowa and his ready accessibility to the same area, also has become strongly interested in the correlation of the Stewartville formation, which contains a small cephalopod fauna of special interest in connection with the correlation of the fauna from the basal part of the Big Horn formation. Both Kay and Miller have been very liberal in communicating observations bearing on this problem to the present writer previous to publication of their results.

Already in 1927, T. E. Savage loaned the author among other

cephalopods also a number of specimens from the basal part of the Big Horn formation on Medicine Mountain, in northern Wyoming. And in recent years both E. O. Ulrich and Edwin Kirk have been active in the study of the Stewartville and related faunas in the upper Mississippi Valley.

All these have been very liberal in offering both information and the loan of specimens to the present writer, without which the publication here presented would have been impossible. The writer here expresses his deep appreciation of the valuable and varied assistance thus afforded.

ENDOCERAS Hall

Genotype: *Endoceras proteiforme* Hall. Pal. New York, vol. 1, 48, pl. 48, fig. 4; pl. 49, figs. 1 a–e (1847); Foerste, Jour. Sci. Labs. Denison Univ., 20, 210, pl. 21, figs. 1–3; pl. 22, figs. 1–3; pl. 23, figs. 1–3; pl. 25, fig. 2 (1924).

The siphuncle apparently is very close, but not in actual contact with the ventral wall of the conch in some of the specimens figured by Hall, and apparently in contact in others, but in no case in broad and conspicuous contact, flattening the median part of the ventral side of the siphuncle.

It is probable that those species in which there is flattened contact between the siphuncle and the ventral wall of the conch are not congeneric with *Endoceras*. The species here described as *Endoceras landerense* belongs to the group having the siphuncle in flattened contact with the ventral wall of the conch.

1. Endoceras landerense new species

Plate III, Fig. 2

The holotype is 120 mm. long. Its lateral diameter enlarges from 40 mm. at the base of the specimen to 46 mm. at a point 65 mm. farther up. Its dorsoventral diameter at the latter point is 43.5 mm., the ventral side of the conch being flattened slightly. There are 4.5 camerae in a length equal to the lateral diameter. The sutures of the septa are directly transverse. The concavity of these septa equals 13 mm. The lateral diameter of the si-

phuncle equals 17 mm., its dorsoventral one being about 15.5 mm., at the base of the specimen. This siphuncle is in contact with the ventral wall of the conch for a width of 11 millimeters. The dorsoventral diameter of the siphuncle equals about two fifths of that of the conch. The surface of the conch appears to have been smooth.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90897.

2. **Endoceras** (?) **paradoxicum** new species

Plate I, Figs. 1, 2

Specimen without any trace of cameration either on its exterior or in its interior; apparently a spiculum or cast of the interior of the uppermost endocone occupying the interior of the siphuncle. After the death and decay of the animal a fine grained sand drifted into the top of the siphuncle and filled its interior as far down as the upper surface of the uppermost endocone, this filling later becoming indurated into the socalled spiess or spiculum.

Originally this spiculum was about 240 or 250 mm. long, but at present only a length of 130 mm. is preserved. One of its lateral sides is preserved for a length of 102 mm. The opposite side is indicated for a length of 25 mm. between points 30 and 55 mm. above the base of the part preserved. In this lateral direction the spiculum enlarges at an angle of 20 degrees, attaining a width estimated at 90 mm. at its top. Its dorsoventral diameter increases from 39 mm. at a point 10 mm. above the base of the part preserved to 68 mm. at a point 90 mm. farther up, indicating an angle of enlargement of 18 degrees in this direction. Where the lateral diameter is 63 mm. the dorsoventral one is 55 mm. At a lateral diameter of 70 mm. most of the cross section is evenly rounded with a radius of curvature of 35 mm., except on its supposed ventral side which is flattened distinctly for a width of about 48 mm. This flattened side is supposed to have faced the ventral wall of the siphuncle which itself probably was flattened

by contact with the ventral wall of the conch. In a lengthwise direction this spiculum is curved convexly with a radius of 400 mm. The opposite outline is correspondingly concave. Crevices across the upper half of the ventral side of this spiculum suggest that the convexity of this outline may have been increased by separation at these fractures, but this still leaves a perceptible convex curvature along the lower half of the specimen.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90898.

Another anomalous specimen was described recently by A. K. Miller, from the same horizon and general area, under the name *Endoceras problematicum* (*18*). In this specimen both the dorsal and the lateral outlines of the siphuncle curve convexly in a manner unknown among typical Endoceroids, but suggestive of some more or less curved conch. The spiculum of this specimen is marked on its ventral side by a well defined longitudinal groove 23 mm. wide and 2 mm. deep. Possibly these two specimens are related, at least generically, but this can not be determined definitely in the present state of our knowledge of their structure.

NANNO Clarke

Genotype: *Nanno aulema* Clarke. Amer. Geol., 15, 207, pl. 6, figs. 1–8 (1894); Foerste, Jour. Sci. Labs. Denison Univ., 27, 69, pl. 32, fig. 14 (1932).

The non-camerated apical end of the genotype enlarges both laterally and dorsoventrally for a length of 12 to 15 mm. and then contracts rapidly, especially on its dorsal side, to form the true siphuncle. The camerated part of the conch begins immediately above that part of the apical end at which contraction takes place. The line at which this contraction takes place slopes obliquely downward from the ventral toward the dorsal side of this part of the apical end.

In *Cameroceras*, as typified by *Cameroceras trentonense* Conrad, the apical end enlarges in a similar manner, but later, when

cameration begins, there is no perceptible contraction at the point where the siphuncle is supposed to begin.

Nothing is known of the apical end of the genotype of *Endoceras*, namely *Endoceras proteiforme* Hall. It scarcely needs statement that identifications with this species, based on specimens outside of the general New York area, and especially those made from other horizons, should be looked on with suspicion until very exact comparisons have been made.

3. Nanno walcotti new species

Plate VIII, Figs. 2, 3

The holotype is 88 mm. long and consists of a short length of the camerated part of the conch beneath which the siphuncle and the preseptal cone are exposed. The diameter of the camerated part at a point 70 mm. above the lower end of the preseptal cone is estimated at 30 mm. Here 5 camerae occupy a length of 30 mm. The sutures of the septa are directly transverse, except in the immediate vicinity of the siphuncle where they curve slightly downward. The concavity of the septa equals almost 5 mm. The siphuncle is in contact with the ventral wall of the conch, possibly for a width of 5 mm. At a point 61 mm. above the base of the specimen the lateral diameter of the siphuncle is 12.5 mm., its dorsoventral one being about 1 mm. less. Beneath this level the siphuncle enlarges laterally to 13.5 mm. at a point 38 mm. above the base, then increases rather suddenly to 15.5 mm. at a point 36 mm. above this base, and more gradually to 17.5 mm. at a point 22 mm. above the base. Then there is a contraction laterally to 16.5 mm. at 18 mm. above the base and a sudden contraction to 14 mm. in a length of 2 mm., beneath which the preseptal cone contracts more evenly as far as the blunt initial end. Septal annulations occur ventrolaterally at 36, 29, 23, and 18 mm. above this apical end. These annulations slope downward in a dorsad direction, being subparallel to the line of contact of the septa with the siphuncle farther up. The abnormal feature consists in the conspicuous elevation of that part of the ventral

side of the siphuncle which extends from 18 to 37 mm. above the apical end. No annulations occur beneath the 18 mm. level.

Occurrence: Harding quarry, 2.5 miles northwest of Canyon City, Fremont county, Colorado. In the basal part of the Fremont formation. Collected by C. D. Walcott. U. S. National Museum, no. 90899.

PROBILLINGSITES Foerste

Genotype: *Probillingsites welleri* Foerste. A Restudy of American Orthoconic Silurian cephalopods. Denison Univ. Bull., Jour. Sci. Labs., 23, 318, pl. 71, figs. 2 A, B (1928).

Species differing from typical *Billingsites* by the absence of strong sigmoid reversal of curvature of the sutures of the septa along the lower part of their lateral course. Moreover, there is no tendency toward confluence of these sutures ventrolaterally. Instead, these sutures rise continuously and with very little flexure from the ventral toward the dorsal side of the conch, as far as known, remaining discrete along the entire length of their course.

4. **Probillingsites milleri** new species

Plate I, Fig. 3

The holotype is 29 mm. long laterally. Its basal part is rounded in a lateral direction with a radius of curvature of 7.5 mm. Its maximum lateral diameter at a point 19 mm. above its base is 21.5 mm. Here the radius of curvature of its lateral outlines is 30 mm. The contraction of the conch toward the aperture is slight, as far as preserved. Dorsoventrally the conch attains a diameter of 17 mm. at a point 12 mm. above its base, but its original diameter in this direction may have been greater. The sutures of 5 septa cross the specimen in a dorsoventral direction rising at an angle of 21 to 27 degrees with the horizontal toward its dorsal side, this angle increasing slightly toward the top of the series. These sutures are equally distant from each other, the 5 occurring in a total length of 8 mm. dorsally, where they form broad saddles. The lowest of these sutures is indicated only as

an angulation around the margin of the septum exposed at the base of the conch, the latter having a concavity of 4 mm. The siphuncle is poorly indicated, and is located distinctly ventrad of the center of the conch.

Occurrence: Elkador, Iowa, from the asylum quarry just above the roadway along the river. From beds two feet thick at a level of 60 feet above the river level, in the *Catazyga uphami* bed of the upper Prosser limestone. Collected by E. O. Ulrich and Edwin Kirk. U. S. National Museum, no. 90900.

BILLINGSITES Hyatt

Genotype: *Ascoceras canadense* Billings. Geol. Surv. Canada, Rept. Progress for 1853–56, 310 (1857); Foerste, in Twenhofel, Geology of Anticosti Island, Geol. Surv. Canada, memoir 154, 260, pl. 40, fig. 3 (1928).

Specimens consisting of oviform, bulb-like bodies which are regarded as gerontic enlargements of the upper part of conchs whose lower portions are unknown. These oviform bodies are depressed dorsoventrally and their lower ends usually are rounded, their upper ends being elongated for a short distance into a neck. The rounded end at the base is formed by a septum which is deeply concave when viwed from above, and whose lateral margin frequently may be detected readily on close observation. This margin slopes downward in a ventrad direction. Vertical dorsoventral sections through the center of these bodies show that subsequent septa are closely crowded on the ventral half of the conch but are widely separated dorsally, rising to consecutively higher levels at the dorsal outline. On the exterior of casts of the interior of the conch frequently all septa terminate ventrally at a single suture, though slight separation, especially along the median part of the ventral side, is not uncommon. Dorsally however, the sutures are widely separated, and rise to consecutively greater heights, forming conspicuous dorsal saddles. Laterally the sutures limiting these saddles frequently unite into a single curved line from which the various saddles appear to branch. The siphuncle at the base of these oviform bodies is strongly ventrad of the center of the conch, but not in contact

with its ventral wall. The lower segment of the siphuncle tends to be globular or even a little elongated in some specimens, but usually the remaining segments are short, flat, and disc-like, chiefly owing to the crowding of the septa. Where transverse markings occur on the surface of the shell, these curve more or less distinctly downward on the ventral side of the conch. It is assumed that the lower missing part of the conch was curved lengthwise, with its convex outline ventral, the siphuncle being located ventrad of the center of the conch.

Species referable to this genus are not known at present below the level of the Stewartville and Big Horn formations. They range to the top of the Richmond, and apparently enter the basal Silurian.

5. **Billingsites landerensis** new species

Plate I, Figs. 4, 5

The holotype includes only the gerontic bulb-like enlargement of the upper part of the conch. This is 56 mm. long. Its basal part is rounded in a lateral direction with a radius of 6 mm. Its lateral diameter equals 29 mm. at a point 36 mm. above its base, diminishing to approximately 25 mm. at the aperture. The dorsal outline has a radius of curvature of approximately 50 mm. along almost its entire length. The lateral outlines have a radius of curvature of 25 mm. along their lower third, changing to 80 mm. farther up. The maximum dorsoventral diameter is 25 mm., the ventral side being distinctly flattened for a width of 22 mm. Apparently a part of this flattening was original, but there is no doubt of this ventral side having been crushed after the death of the animal, probably with some increase in the original amount of flattening. The lateral margin of the plane of contact of this bulb-like enlargement with the earlier part of the conch slopes downward from a point 14 mm. above its base dorsally to a point 8.5 mm. above this base ventrally. From this lateral margin the sutures of 4 septa arch upward on the dorsal side of the conch producing saddles of successively greater width. The broad crests of these dorsal saddles are almost directly transverse

across the dorsal side of the conch, rising to elevations of 26 mm., 35.5 mm., 55.6 mm., and 40.7 mm. in ascending order. Dorsolaterally these saddles curve downward until their maximum lateral extent along the curving dorsal side equals 36, 48, 51, and 54 mm. in ascending order. The lower parts of these saddles curve inward until they come into contact with each other along a single moderately curved line extending from the uppermost saddle to the line of attachment where the latter forms an abruptly recurving angle with single ventral suture. The resulting angles here are 16 mm. apart dorsally. The neck-like extension of the upper part of the specimen above the uppermost saddle is 6 mm. long.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90901.

6. **Billingsites multicameratus** Miller

Plate I, Fig. 6

Billingsites multicameratus A. K. Miller. The Cephalopods of the Big Horn Formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 243, pl. 10, figs. 6–8 (1932).

Specimen closely resembling the type of *Billingsites multicameratus* A. K. Miller as figured from the basal part of the Big Horn formation of the area west of Lander, Wyoming, in its size, lateral outline, and the relative intervals between the successive dorsal saddles. Of these dorsal saddles, only 4 are distinctly indicated, but apparently there is a trace also of a fifth saddle at the proper interval at the extreme top of the specimen, as far as preserved, the short neck, with which the living chamber usually terminates, not being preserved.

Occurrence: Medicine Mountain, in the northeastern part of Big Horn county, Wyoming, about 15 miles south of the Montana state line and 4 or 5 miles west of the Sheridan county line. From

the basal part of the Big Horn formation. Collection of T. E. Savage.

GEISONOCERAS Hyatt

Genotype: *Orthoceras rivale* Barrande, Systême silurien du centre de la Bohême, vol. 2, text, pt. 3, p. 383 (1874); pl. 209, figs. 1–5 (1866).

Conchs transversely banded, the bands relatively wide and flat, their upper margins abruptly delineated, their lower margins apparently invaginating into the top of the underlying bands. The siphuncle of the genotype expands but slightly within the camerae.

GEISONOCERINA new genus

Genotype: *Orthoceras wauwatosense* (Whitfield). Geol. Wisconsin, vol. 4, 297, pl. 19, fig. 2; *Geisonoceras wauwatosense* Foerste, Jour. Sci. Labs. Denison Univ., 23, 250, pl. 53, figs. 2 A–D, 3 (1928).

Conchs differing from typical *Geisonoceras* in being ornamented by numerous, close, raised transverse lines or striae, instead of comparatively broad bands. The grouping of species under these generic terms is extremely artificial in either case.

7. Geisonocerina landerensis new species

Plate II, Figs. 6, 7; Plate XI, Fig. 4

The holotype is 100 mm. long. It is faintly curved lengthwise, the arching of its concave outline equalling 2 mm. within this length. Its section is circular. Its diameter increases from 11 mm. at its base to 21 mm. at its top. At its upper end there are 5 camerae in a length of 23 mm. The sutures of the septa undulate slightly, possibly owing to distortion. The surface of the shell is crossed by numerous distinct transverse striae, about 18 in a length of 10 mm.; these slant downward toward the concave side of the conch, being more nearly horizontal on its convex side. These striae cross the sutures of the septa. U. S. National Museum, no. 90902-A. (Plate II, fig. 6.)

A second specimen, 118 mm. long, also is slightly curved. This specimen enlarges from a maximum diameter of 11.5 mm. at its base to 20 mm. at a point 108 mm. farther up. The number of camerae in a length equal to the diameter of the conch equals 4 both at the base and the top of the specimen. U. S. National Museum, no. 90902-B. (Plate XI, fig. 4.)

A third specimen, 112 mm. long, includes a living chamber of which a length of 85 mm. is preserved. The diameter of this chamber increases from 27 mm. at its base to 33 mm. at a point 66 mm. farther up. A faint annular contraction takes place 10 mm. beneath the top of the specimen, and this contraction is 10 mm. wide vertically. It represents an annular thickening of the interior of the shell near the top of the chamber. The lower 4 camerae have a total length of 21 mm., the two overlying camerae having lengths of 4.2 mm. and 3.8 mm. in ascending order. The conch evidently had attained its gerqntic stage of growth. U. S. National Museum, no. 90902-C. (Plate II, fig. 7.)

Several associated specimens have attained gerontic stages of growth, with diameters of 29, 36, and 37 mm. at the top of the phragmacone.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, nos. 90902-A, B, C.

KIONOCERAS Hyatt

Genotype: *Orthoceras doricum* Barrande, Système silurien du centre de la Bohême, vol. 2, text, pt. 3, (1874), pl. 269 (1868).

Nine specimens are figured on the plate cited above under the name *Orthoceras doricum.* All of these have numerous fine and closely arranged transverse striae. Several of them also have vertical striae, usually only 1 or 2 in number, between each pair of vertical ribs. They are most numerous on the surface of the shell of the specimen here figured first.

In the species described by A. K. Miller under the name *Kionoceras paucicostatum*, the surface of the shell is cancellated

by numerous fine and closely arranged striae which cross each other both laterally and longitudinally.

8. Kionoceras paucicostatum Miller

Plate V, Fig. 5

Kionoceras paucicostatum. A. K. Miller. The Cephalopods of the Bighorn formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 247, pl. 11, figs. 2–4 (1932).

The specimen here figured is 70 mm. long and was compressed after the death of the animal. In its present condition its maximum diameter enlarges from 38 mm. to 44 mm. in a length of 55 mm. There are 11 vertical, narrowly angular ribs separated by broad grooves varying from 1.5 to 2 mm. in depth. There are 11 camerae in a length of 44 mm., the sutures of the septa curving slightly upward toward the crest of the ribs. The surface of the shell is minutely cancellated by numerous transverse and vertical raised lines, the transverse lines being somewhat more numerous and numbering about 11 in a length of 2 millimeters.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90903.

Remarks.—The holotype, figure by A. K. Miller in the publication cited above, includes only the upper part of the conch, but this is of special interest on account of the convex curvature of its ventral outline and the conspicuous tapering of the conch toward the aperture at a gerontic stage of growth. These features are much more common among the Spyroceroids than among the Kionoceroids. It is shown, for instance, by the specimen of *Spyroceras hastiformum* figured by Miller in the same publication on his plate 12 as figure 4.

SPYROCERAS Hyatt

Genotype: *Orthoceras crotalum* Hall, Pal. New York, vol. 5, pt. 2, pls. 42, 82, 113, (1879). *Spyroceras crotalum* Hyatt, Proc. Boston Soc. Nat. Hist., 22, 276 (1884).

In the genotype the conch is crossed transversely by strong, sharply defined, and rather distant annulations. The vertical striae are very fine, almost microscopic, and closely crowded. It is customary to assign to this genus also species in which the vertical striae are relatively coarse, in some species almost rib-like.

9. Spyroceras cf. anellus (Conrad)

Plate XI, Fig. 6

Spyroceras anellus; Foerste, Aug. F. A Restudy of some of the Ordovician and Silurian Cephalopods described by Hall. Denison Univ. Bull., Jour. Sci. Labs., 23, 177, pl. 40, fig. 4 (1928).

The specimen here figured is exposed for a length of 21 mm., its diameter being 8.5 mm., without any appreciable enlargement within this length. Five crests of annulations occur in a length of 9.5 mm. These crests are relatively prominent and narrowly rounded, rising fully half a millimeter above the intervening grooves. There are about 60 faintly indicated vertical lines within the circumference of the conch. These are crossed by still fainter transverse lines, about 5 or 6 in a length of 1 mm.

Occurrence: On the south side of the Middle Fork of the Popo Agie River, about 8 miles west of Lander, in Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90904.

Remarks.—This specimen somewhat resembles *Spyroceras anellus* (Conrad) from the Beloit member of the Black River group at Mineral Point, Wisconsin, but the annulations are relatively less numerous compared with the diameter of the conch.

In a similar manner the specimen figure by Miller under the name *Spyroceras olorus* (Hall) from the Big Horn formation in the Popo Agie River area resembles that species as described from the Trenton formation at Middleville, New York, but the annulations are less numerous in a length equal to the diameter of the conch, their crests are more prominent, and nothing is known of their transverse markings if any originally were present.

10. **Spyroceras** (?) **distoannulatum** new species

Plate VI, Fig. 4

In the absence of any distinct trace of cameration or of any indication of the siphuncle it is impossible to determine the affinities of this specimen. It is assumed to be a cast of the interior of a conch, but how such a cast could escape showing traces of sutures of the septa is unknown.

The specimen is 123 mm. long. Apparently it was compressed after the death of the animal. In its present condition its maximum diameter enlarges from 21 mm. near its base to 27 mm. at a point 81 mm. farther up. The corresponding shorter diameters are 17 mm. and 20.5 mm. One annulation occurs at the extreme top of the specimen, and other annulations occur at successive intervals of 26 mm., 26 mm., and 24 mm., in descending order. The 4 annulations here indicated have a vertical width of 2 mm. and rise above the adjacent part of the surface about one third of a millimeter. They occur in broad and shallow transverse constrictions between which there are correspondingly low and broad enlargements. The segments thus indicated have lengths of 26 mm., 26 mm., 24 mm., 24 mm., and again 24 mm. respectively in descending order, but no annulations occur between the lower segments. Beneath the lowest distinct annulation there are faint transverse markings, the upper 5 occupying a length of 17 mm. and the underlying 5 a length of 14 mm. The significance of these transverse markings can not be determined. In addition to the transverse annulations there are distinct vertical ribs from 1 to 2 mm. in width, some of them almost as distinct as the annulations. These ribs are not equally distant. At two points they are separated by widths sufficient to admit of an additional rib, but none is distinctly indicated here. These ribs occur at intervals admitting of 12 or 13 ribs within the circumference of the specimen if all were present. The transverse annulations slope downward toward one side of the conch at angles of 20 degrees, but this may be due to distortion after the death of the animal.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. From the

basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90905.

Remarks.—A specimen with distant annulations, located approximately at the sutures of the septa, was described by Whiteaves from East Selkirk, Manitoba from the Selkirk member of the Red River formation, and redescribed by Foerste (*19*) under the name *Cycloceras selkirkense*. Possibly a similar location of the annulations occurred also in the Wyoming specimen but this can not be determined from the material at hand.

CENTROCYRTOCERAS Foerste

Genotype: *Cyrtoceras annulatum* Hall, Pal. New York, vol. 1, 194, pl. 41, figs. 4 a–d, 5 (1847); *Cyrtoceras subannulatum* D'Orbigny, Prodr. Pal., vol. 1, p. 1 (1849); Foerste, *Centrocyrtoceras subannulatum*, Jour. Sci. Labs., Denison Univ., 28, 45 (1933); 27, pl. 28, figs. 8 A, B (1932).

Conchs small, curved, cross section nearly circular in genotype, but usually distinctly compressed laterally in other species. Location of siphuncle slightly ventrad of center of conch, segments of siphuncle nearly cylindrical. Annulations usually curving downward laterally, frequently with a slight angularity near the median part of the lateral sides. Usually with fine striae parallel to the annulations.

Species of this type are not known at present above the Trenton formation.

11. Centrocyrtoceras rotundum new species

Plate X, Fig. 6

The holotype is 32 mm. long on its ventral outline, all belonging to the phragmacone. Its dorsoventral diameter enlarges from 6 mm. near its base to 10.6 mm. at a point 28 mm. farther up, the corresponding lateral diameters being almost the same, the one at its top being 10 mm. The cross section of the conch here is faintly more narrowly rounded ventrally than dorsally. The lowest camera is 1 mm. long ventrally; the one at a diameter of 8 mm. is 1.7 mm. long, and that at 10 mm. is 2.5 mm. long. The sutures

of the septa curve downward laterally, the depth of the uppermost lateral lobe being 1 mm. The ventral saddles here are subangular and rise 2 mm. above the low and broadly rounded dorsal ones. At a dorsoventral diameter of 7.4 mm. the concavity of the septum is 0.7 mm., and the passage of the siphuncle through this septum is 0.75 mm. in diameter, its center being located 3.4 mm. from the ventral wall of the conch. The surface of the conch is crossed by transverse annulations which curve downward laterally more strongly than the sutures of the septa, the deepest part of their downward curvature being a little dorsad of the median part of the conch laterally. Dorsally these annulations arch only slightly upward but ventrally they form subangular crests. Between dorsoventral diameters of 8.5 mm. and 11 mm., along an interval of 12.5 mm. ventrally, there are 6 crests of annulations, the lower 3 occupying a length of 5 mm. and the upper 3 a length of 5.7 mm. ventrally. Only a cast of the interior of the conch is preserved and this does not show any transverse striae.

Occurrence: 2 miles northeast of Elkador, Clayton county, Iowa, along highway 13, north of Roberts Creek. In the Upper Prosser, from the upper 25 feet of beds underlying the dolomite. Collected by Edwin Kirk. U. S. National Museum, no. 90906.

BELOITOCERAS Foerste

Genotype: *Oncoceras pandion* Hall. Rept. Supt. Geol. Surv. Wisconsin, 1861, 45; *ibid.*, 1862, 41, fig. 3; Foerste, Jour. Sci. Labs. Denison Univ., 20, 245, pl. 36, figs. 5 A, B; pl. 41, figs. 4 A, B, C (1924).

It was intended to include in the genus *Beloitoceras* relatively short, curved conchs which were laterally compressed, attained their greatest dorsoventral diameter at or above the base of the living chamber, and in which the lower part of the dorsal outline of the living chamber tended to be slightly convex or gibbous. The siphuncle is located near, but not in contact with the ventral wall of the conch, its segments being elongated vertically, instead of subglobular or subnummuloidal in form. The typical specimens occur in the Beloit formation in the Upper Mississippi

Valley, but similar specimens occur as far up as the top of the Richmond.

12. Beloitoceras fremontense new species

Plate X, Fig. 2

The holotype is 38 mm. long, 19 mm. of this length belonging to the living chamber. The radius of curvature of its ventral outline is 40 mm. along the phragmacone and the lower half of the living chamber. That of the concave dorsal outline is 40 mm. along the phragmacone, reversing to convex with a similar rate of curvature along the lower part of the living chamber, returning to concave again toward its top. The dorsoventral diameter of the conch enlarges from 13.5 mm. at a point 12 mm. beneath the living chamber to 18.5 mm. at the maximum gibbosity of the conch, and then decreases to approximately 17.5 mm. at the aperture. The corresponding lateral diameters are 11.5 mm., 16 mm., and approximately 15 mm. The downward curvature of the suture of the uppermost septum is 1 mm. The ventral saddles are a little more narrowly rounded than the dorsal ones and rise slightly higher. At the base of the specimen the siphuncle is almost 1 mm. wide and is almost in contact with the ventral wall of the conch.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90907.

13. Beloitoceras popoagiense new species

Plate X, Fig. 3

The holotype is 29 mm. long, 18 mm. of this length belonging to the living chamber. Its ventral outline has a radius of curvature of 30 mm. along all but the upper half of the living chamber which is more rapidly curved. Its dorsal outline is faintly gibbous along the top of the phragmacone and the lower three-fifths of the living chamber, reversing to faintly concave farther up. Four camerae

occupy a length of 10 mm. ventrally. The downward lateral curvature of the sutures of the septa equals 2 mm.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90908.

Remarks.—This specimen is closely similar to the type of *Beloitoceras fremontense,* but its camerae are distinctly taller, and the sutures of the septa curve farther downward laterally.

The specimen identified by A. K. Miller as *Beloitoceras plebeium* (Hall) differs from the type of that species, found in the Beloit or Platteville member of the Black River in Wisconsin, in the stronger lengthwise curvature of the conch, in the greater downward curvature of the sutures of the septa laterally, and in the more conspicuous rise of the ventral saddles of these sutures. In all of these features it closely resembles the species here described as *Beloitoceras popoagiense,* with which it is identified.

14. **Beloitoceras landerense** new species

Plate IV, Fig. 3

The holotype is 62 mm. long on its ventral outline, 35 mm. of this length belonging to the living chamber. The aperture is almost directly transverse. The radius of curvature of this outline is 40 mm. along the phragmacone, changing to 50 mm. along the living chamber. Its dorsal outline is nearly straight along that part of the phragmacone preserved and also along the lower 10 mm. of the length of the living chamber, but farther up it changes to distinctly concave with a radius of curvature of 50 mm. The dorsoventral diameter of the conch enlarges from 25 mm. at its base to 32 mm. at the base of the living chamber and then contracts to 29 mm. at the aperture. The corresponding lateral diameters are 21 mm., 26 mm., and 21 mm. respectively. At the top of the phragmacone there are 6 camerae in a length of 26 mm. ventrally, enlarging from a length of 3 mm. at the lower end of the specimen to 5 mm. at the top of the phragmacone. The uppermost suture curves 2 mm. downward laterally, the

ventral saddle being more angular and rising a little higher than the dorsal one. The passage of the siphuncle through the septum at its base has a lateral diameter of 2.2 mm. and its center is about 3 mm. from the ventral wall of the conch. The form of the segments of the siphuncle is unknown.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90909.

Remarks.—The reference of this species to *Beloitoceras*, rather than to *Richardsonoceras*, is due to the straightness of its dorsal outline along the top of the phragmacone and the lower part of the living chamber. Concave curvature is present along this outline only along the upper part of the living chamber and also along the lower part of the phragmacone, beneath the level of 20 mm. below the base of the living chamber. In typical *Richardsonoceras* the dorsal outline is distinctly concave along its entire length, including the upper part of the phragmacone and the basal part of the living chamber.

NEUMATOCERAS new genus

Genotype: *Neumatoceras gibberosum* Foerste.

The genus *Neumatoceras* differs from *Beloitoceras* chiefly in being distinctly humped along the upper part of the ventral outline of the phragmacone, the maximum dorsoventral diameter usually being at a distinct interval beneath the base of the living chamber ventrally. From this level of maximum dorsoventral diameter the conch usually tapers conspicuously toward the aperture. The dorsal outline along the upper part of the phragmacone and all of the living chamber tends to be relatively straight, with faint incurvature at top and along the lower part of the phragmacone.

Neumatoceras gibberosum and *Neumatoceras nutans* are from the basal part of the Big Horn formation of Medicine Mountain, in north central Wyoming. *Neumatoceras breviposticum* A. K. Miller, is from the area west of Lander, in central Wyoming. *Neumatoceras canyonense* is from the area northwest of Canyon

City, Colorado, and apparently occurs also west of Lander, in Wyoming. The species described here as *Neumatoceras* (?) *milleri* also is from Medicine Mountain, but its largest dorsoventral diameter is at the base of the living chamber.

In the absence of any adequate knowledge of the phragmacone, it is impossible to place with certainty such specimens as the one figured by Foerste as *Winnipegoceras* sp. in his Cephalopods of the Red River formation of Southern Manitoba (*20*), or the closely similar one figured here under *Neumatoceras* sp. (Plate V, fig. 4) from the North Fork of Bear Trap creek, in north central Wyoming. In the unnamed form described here from Eight Mile Mountain, north of Canyon City, Colorado (Plate V, figs. 1, 2, 3), the conch attenuates more slowly toward the aperture than is usual in the more typical forms of *Neumatoceras*.

Equal uncertainty prevails as to the relationship of *Oncoceras tumidum* Schuchert (*21*), from Southern Baffin Land, and *Westonoceras* (?) *contractum* Foerste and Savage (*22*), from the Hudson Bay area.

15. Neumatoceraras gibberosum new species

Plate II, Figs. 3, 4

The holotype is 65 mm. long and is distinctly geniculate along its ventral outline, its maximum gibbosity being at the fifth camera beneath the living chamber. Here its dorsoventral diameter is 38 mm., contracting to 35 mm. at the base of the living chamber, and to 29 mm. at the aperture. Beneath its maximum geniculation the conch contracts in an apicad direction but the rate of contraction can not be determined. Its lateral diameter contracts from a maximum of 26 mm. to 20 mm. at the aperture. The dorsal outline of the conch is almost straight for a length of 40 mm., all that is preserved. The ventral length of the uppermost camera is 3 mm., that of the 4 underlying camerae being 5 mm. The downward curvature of the upper sutures of the septa is about 5 mm. At the tenth suture beneath the top of the living chamber the siphuncle is 4 mm. in diameter, but its distance from the ventral wall of the conch can not be determined

with accuracy, though apparently equalling about 2 mm. (Plate II, fig. 3.)

A second specimen, 50 mm. long, has a dorsoventral diameter enlarging from 24 mm. at its base to 36 mm. at the fifth suture below the living chamber, and then contracting to 32 mm. at the base of this chamber, this contraction continuing toward the aperture. The dorsal outline, as far as preserved, is nearly straight, but is slightly concave just beneath the aperture. (Plate II, fig. 4.)

Occurrence: Medicine Mountain, in the northeastern corner of Big Horn County, Wyoming, about 15 miles south of the Montana line and 4 or 5 miles west of the Sheridan county line. From the basal part of the Big Horn formation. Collection of T. E. Savage.

16. **Neumatoceras nutans** new species

Plate II, Figs. 1, 2

The holotype is 73 mm. long in a straight line, its living chamber having a length of 34 mm. ventrally. Its maximum geniculation is at the second camera beneath the living chamber where its dorsoventral diameter is 41 mm. and its lateral one is 26.5 mm. Here the radius of curvature of its ventral outline is 30 mm. Thence the conch contracts to a dorsoventral diameter of 31 mm. and a lateral one of about 20 mm. at the aperture. The dorsal outline is nearly straight except about 8 mm. beneath the aperture where it has a concave curvature with a radius of 10 mm. At a dorsoventral diameter of 41 mm. the siphuncle is 4.2 mm. in diameter and its distance from the ventral wall of the conch is 4.6 mm. Its segments are nearly cylindrical.

Occurrence: Medicine Mountain, in the northeastern corner of Big Horn County, Wyoming, about 15 miles south of the Montana line and 4 or 5 miles west of Sheridan county. From the basal part of the Big Horn formation. Collection of T. E. Savage.

Remarks.—This species is closely similar to the latter but differs in its larger size, the greater length of the camerae, the smaller downward curvature of the sutures of the septa and the smaller rise of the ventral saddles.

17. **Neumatoceras breviposticum** (Miller)

Plate VII, Fig. 5

Beloitoceras breviposticum A. K. Miller. The Cephalopods of the Bighorn Formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 283, pl. 28, figs. 9–12 (1932).

This is one of the smaller species of the genus. It shows the characteristic geniculation of the ventral outline of the conch at a distinct distance beneath the base of the living chamber, the upper part of the conch contracting as far as the aperture. The holotype and figured specimen are in the museum of the University of Missouri.

The fragment here referred to the same species is of interest chiefly owing to the presence of narrow transverse ribs which curve increasingly downward in a ventrad direction, the crests of 5 ribs occurring in a length of 8 mm.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90910.

18. **Neumatoceras canyonense** new species

Plate III, Figs. 3, 4

The holotype is 66 mm. long measured in a straight line, the maximum length of the living chamber being 18 mm. The ventral outline of the greater part of the phragmacone is not preserved, but enough of the adjacent part of the conch is preserved to indicate that this outline was geniculated and that its greatest dorsoventral diameter was several camerae beneath the base of the living chamber ventrally. The radius of concave curvature of the dorsal outline is 40 mm. along most of the phragmacone but is shortened to 30 mm. at midlength of the latter; along the living chamber it is about 50 mm. The dorsoventral diameter increases from 10 mm. at the base of the specimen to 12.5 mm. at a point 10 mm. farther up; its maximum length farther up is estimated at 27 mm. and is located about 15 mm. beneath the

ventral margin of the base of the living chamber; at the base of this chamber it is 23.5 mm., decreasing to 15.5 at the aperture. The corresponding lateral diameters are 9.5 mm., 11 mm., 23 mm., 22 mm., and 14 mm. Dorsally there are 4 camerae in a length of 11.5 mm. along the upper half of the phragmacone. The downward curvature of the uppermost suture laterally is 5 mm., its ventral saddle rising about 7 mm. above its dorsal one.

Occurrence: Eight Mile Mountain, north of Parkdale road, between 4 and 8 miles north of Canyon City, Colorado. Basal part of Fremont formation. Collected by S. W. Loper. U. S. National Museum, no. 90911.

19. **Neumatoceras** cf. **canyonense** Foerste

Plate III, Fig. 5

The holotype is 40 mm. long in a straight line. Its ventral outline has a radius of curvature of 20 mm. along its more gibbous part, increasing to 40 mm. along the lower part of the phragmacone and along the living chamber. Its dorsal outline appears to have been almost straight. Its dorsoventral diameter increases from 17 mm. at its base to 25.5 mm. at midlength of the third camera beneath the living chamber and then decreases to 24 mm. at the base of this chamber, and to approximately 16.7 mm. at the aperture. The corresponding lateral diameters are 15 mm., 21.5 mm., 20.3 mm., and approximately 15 mm. The middle 4 camerae of this specimen are each 6 mm. long ventrally, the one beneath this series and the one above the latter being 5 mm. long. Dorsally the lower 4 camerae occupy a length of 10 mm., the overlying 2 having a total length of 3 mm. The suture of the uppermost septum curves downward 5 mm. laterally, and its ventral saddle rises 12 mm. above its dorsal one. The passage of the siphuncle through the septum at the base of the specimen is 2.5 mm. wide and is about 1 mm. from the ventral wall of the conch.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90912.

Remarks.—This specimen evidently is closely related to the type of *Neumatoceras canyonense* and the differences are only slight. The conch is more compressed laterally, the camerae are longer, the geniculation of its ventral outline is more rapidly curved, and the ventral half of the suture at the base of the living chamber rises more strongly above the level of the dorsal one; but in each case the difference is moderate.

20. **Neumatoceras** (?) **milleri** new species

Plate IV, Fig. 4

The holotype is 51 mm. long, measured in a straight line, the maximum depth of the living chamber laterally being 19 mm. Its ventral outline has a radius of curvature of 60 mm. along the lower three-fourths of the length of the phragmacone, shortening to 30 mm. along the upper 4 camerae, and to 15 mm. along the lower part of the living chamber. Its dorsal outline has a radius of concave curvature of 20 mm. along its lower part, increasing to 40 mm. along the upper part of the phragmacone and most of the living chamber. Its dorsoventral diameter increases from 10 mm. at its base to 25.3 mm. just beneath the ventral margin of the base of the living chamber, and then decreases to 22 mm. at the aperture. The corresponding lateral diameters are 7.2 mm., 18.6 mm., and 15 mm., the maximum lateral diameter being located nearly 7 mm. above the lowest part of the suture at the base of the living chamber. Ten camerae occupy a length of 32.7 mm. ventrally, the lower 4 occupying a length of 12.7 mm., the middle 4 a length of 15 mm., and the upper 2 a length of 5 mm. The uppermost suture curves downward laterally about 5 mm., its ventral saddle rising about 2 mm. above the level of the dorsal one. On the lateral side of the living chamber there are faint traces of transverse ribs curving increasingly downward in a ventrad direction, indicating a deep hyponomic sinus.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90913.

Remarks.—This species is similar to *Neumatoceras* in the rapid attenuation dorsoventrally of its relatively short living chamber toward the aperture, but it differs from typical representatives of the genus in attaining its largest dorsoventral diameter at the junction of the phragmacone and the living chamber.

21. **Neumatoceras** (?) sp. (Bear Trap Creek)

Plate V, Fig. 4

The specimen here figured is 30 mm. long and consists of a living chamber with two camerae still attached. Its convex ventral outline has a radius of curvature of 40 mm. Its dorsal outline has a radius of concave curvature of 20 mm. along all but the basal part of the living chamber and the immediately adjacent part of the phragmacone which are slightly gibbous apparently. The cross section is oval, its ventral part being more narrowly rounded. Its dorsoventral diameter decreases from 25 mm. just beneath the base of the living chamber to 16 mm. at the aperture, the corresponding lateral diameters being 20 mm. and 13.5 mm. The uppermost camera is 2 mm. long laterally. Nothing is known of the length of the camerae of the remainder of the phragmacone. The suture of the uppermost septum curves distinctly downward for a depth of 3 mm. laterally, its ventral saddle being only slightly higher than its dorsal one. The concavity of this septum in a lateral direction is about 3 mm. The siphuncle appears to be 2 mm. in diameter, its center being about 3 mm. from the ventral wall of the conch. The surface of the cast of the interior of the conch is faintly striated transversely, the raised lines here slanting downward at an increasing rate in a ventrad direction, thus indicating a relatively narrow and deep hyponomic sinus, its basal part being rounded.

Occurrence: Head of North Fork of Bear Trap Creek, between the head waters of Beaver Creek and the North Fork of Powder River, in the southeast foot hills of the Big Horn Mountains, in west central Johnson County, Wyoming. In the basal sandstone of the Big Horn formation, here 3 feet thick. Collected by Edwin Kirk. U. S. National Museum, no. 90914.

22. **Neumatoceras** (?) sp. (Eight Mile Mt.)

Plate V, Figs. 1, 2, 3

The specimen figured here is 50 mm. long, 38 mm. of this length belonging to the living chamber. Its dorsoventral diameter decreases from 36 mm. at the base of the third camera beneath the living chamber to 34 mm. at the base of this chamber, and to 30 mm. at the aperture. The lateral diameter decreases from 27 mm. at the base of this chamber to about 21 mm. at its top. The 3 camerae at its base occupy a total length of 26 mm. ventrally. The sutures of the septa curve downward 5 or 6 mm. laterally, their ventral saddles rising only slightly over their dorsal ones. The siphuncle is nearly 3 mm. in diameter and is located near, but not in contact with the ventral wall of the conch.

Occurrence: Eight Mile Mountain, north of Parkdale road, between 4 and 8 miles north of Canyon City, Fremont county, Colorado. In the basal part of the Fremont formation. Collected by S. W. Loper. U. S. National Museum, no. 90915.

WINNIPEGOCERAS Foerste

Genotype: *Cyrtoceras laticurvatum* Whiteaves, Geol. Surv. Canada, Pal. Foss., vol. 3, pt. 3, 224, text fig. 14 (1897); *Winnipegoceras laticurvatum* Foerste, Contrib. Mus. Pal. Univ. Michigan, 3, no. 3, 56, pl. 9, figs. 1, 2 (1928).

The holotype resembles the genus here called *Neumatoceras* in the enlargement of the conch to a point distinctly below the base of the living chamber, the remainder of the phragmacone and the lower part of the living chamber tapering thence upward. The conch of *Winnipegoceras*, however, attains a much larger size, curves more strongly lengthwise considering its size, and the living chamber is much longer.

23. **Winnipegoceras laticurvatum** (Whiteaves)

Plate IV, Fig. 2

Cyrtoceras laticurvatum Whiteaves. Geol. Surv. Canada, Pal. Foss., vol. 3, pt. 3, p. 224, text fig. 14 (1897).

Winnipegoceras laticurvatum Foerste. Contrib. Mus. Pal. Univ. Michigan, 3, no. 3, 56, pl. 9, figs. 1, 2 (1928).

The specimen figured here is 135 mm. long, about 90 mm. of this length belonging to the living chamber. The radius of curvature of its convex ventral outline equals about 250 mm., that of its concave dorsal outline being more nearly 140 mm. The dorsoventral diameter of the conch diminishes from 48 mm. at the base of the fifth camera beneath the living chamber to 41 mm. at the base of this chamber, and to 37 mm. at a point 45 mm. farther up. The rate of diminution along the remainder of the living chamber is unknown but apparently was slight. The lateral diameter decreases from 29 mm. at the base of the living chamber to 25 mm. at a point 35 mm. farther up, the rate of diminution farther up apparently being slight. Faint transverse markings across the living chamber suggest that the margin of the aperture sloped downward ventrally. The 6 camerae still attached to the living chamber are about equal in length, their total length being 41 mm. when measured along the median part of their lateral sides. The sutures of the septa curve conspicuously downward laterally, the depth of the resulting lobes being 10 to 12 mm. The cross section of the conch is more narrowly rounded ventrally than dorsally, resulting in more angular saddles ventrally than dorsally.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90916.

RICHARDSONOCERAS Foerste

Genotype: *Cyrtoceras simplex* Billings. Geol. Surv. Canada, Rept. Progress for 1853–56, 313 (1857); *Richardsonoceras simplex* Foerste, Denison Univ. Bull., Jour. Sci. Labs., 28, 91, pl. 26, figs. 1 A, B; 2, 3, 4; 5 A, B (1932–33).

The genus *Richardsonoceras* differs from *Beloitoceras* in including conchs which are more strongly curved lengthwise, the dorsal outline being distinctly concave along the living chamber as well as along the phragmacone. The conchs tend to be more slender

and to enlarge less rapidly dorsoventrally. The segments of the siphuncle in the genotype are more nearly subglobular. This genotype is from the Black River formation, but similar species range much higher in the Ordovician.

It is doubtful whether the species described here as *Richardsonoceras subcuneatum* should be referred to this genus. The ventral part of its cross section is more angular than in typical forms of the latter. In this respect it resembles the cross section of the genotype of *Oxygonioceras*, from the Silurian of Bohemia. In that Silurian genus the segments of the siphuncle are similar in form to those of *Richardsonoceras*. In the species here described as *Richardsonoceras subcuneatum*, however, the segments of the siphuncle are elongated vertically.

The species described by Whiteaves (*23*) under the name *Cyrtoceras cuneatum*, from the Silurian of Stonewall, Manitoba, has a cross section similar to that of *Oxygonioceras*, but Whiteaves indicates the location of the siphuncle slightly ventrad of the center of the conch. Unfortunately this location of the conch is questionable, and can not be verified in the absence of the type, which can not be found.

24. **Richardsonoceras wyomingense** new species

Plate III, Fig. 1

The specimen figured is 165 mm. long, measured in a straight line. Along the upper part of the phragmacone and the basal part of the living chamber, for a length of 100 mm., the radius of curvature of its ventral outline equals about 160 mm. The ventral side of the living chamber is preserved for a length of 45 mm. The dorsoventral diameter of the conch at a point 90 mm. beneath the living chamber equals 52 mm.; thence it enlarges to 62 mm. at the base of the living chamber. At this upper level the lateral diameter equals 41.5 mm., at least in the present condition of the conch. The ventral side of the cross section is more narrowly rounded than its dorsal part, but there is no conspicuous angulation as in the preceding specimen. At midlength of the phragmacone, where its dorsoventral diameter is 56 mm.,

there are 7 camerae in a length of 40 mm. measured ventrally. Near the top of the phragmacone there are only 6 camerae in this length. The uppermost camera is only 4 mm. long, the conch evidently having attained its gerontic stage of growth. Near the lower end of the specimen the sutures of the septa curve downward nearly 10 mm. laterally, rising only slightly higher ventrally than dorsally. At the top of the phragmacone this downward curvature of the septa equals only 5 mm. The siphuncle is not preserved, but is assumed to have been located near the ventral wall of the conch.

Compared with the preceding specimen, the cross section of this conch is not conspicuously angular ventrally, and the ventral saddles are relatively low.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90917.

25. **Richardsonoceras** (?) **subcuneatum** new species

Plate VII, Figs. 3, 4

Only a part of the phragmacone remains. In a straight line this is 145 mm. long. Its concave dorsal outline is preserved for a length of 55 mm. Within this length the radius of curvature of the dorsal outline is 50 mm. At the top of this outline the dorsoventral diameter of the conch is 73 mm. and its lateral one is 42 mm. The cross section of the conch here is ovate, its dorsal side having a radius of curvature of 20 mm. while its ventral side is abruptly rounded, the lateral sides here converging at an angle of almost 90 degrees. At the top of the specimen there are 6 camerae within a length of 31 mm. when counted along the median part of its lateral sides. Along the ventral outline this is estimated to be equivalent to 6 camerae in about 50 mm. The sutures of the septa here curve downward laterally about 11 mm., rising strongly ventrally to a height of about 25 mm. above their dorsal parts. In consequence, the ventral saddles appear angular and conspicuously elevated. The concavity of the septa here

equals 5 mm. The passage of the siphuncle though the septum is 4 mm. in diameter, its center being about 4 mm. from the ventral wall of the conch. Its segments are elongated vertically and are about 3 mm. in diameter. At the lower end of the specimen there are 6 camerae in a length of 21 mm. measured laterally.

Occurrence: Eight Mile Mountain, north of the Parkdale road, between 4 and 8 miles north of Canyon City, Fremont County, Colorado. In the basal part of the Fremont formation. Collected by S. W. Loper. U. S. National Museum, no. 90918.

ONCOCERAS Hall

Genotype: *Oncoceras constrictum* Hall. Pal. New York, vol. 1, 197, pl. 41, figs. 6 a–f, 7 a–d (1847); also Foerste, Jour. Sci. Labs. Denison Univ., 20, 240, pl. 39, figs. 2 A, B; 3, 4 (1924).

The holotype is a relatively small conch, curved, distinctly gibbous on its dorsal side at the top of the phragmacone and base of the living chamber, where it also reaches its greatest lateral diameter, contracting then distinctly toward the aperture. This holotype occurs in the Trenton of New York but the genus ranges upward to the top of the Richmond.

26. **Oncoceras parvum** new species

Plate X, Fig. 4

The maximum length of the holotype in a straight line is 37 mm. Its ventral outline has a radius of convex curvature of 20 mm. Its dorsal outline has a radius of concave curvature of 10 mm. along most of the phragmacone, reversing to convex, with a radius of 20 mm., along the upper part of the phragmacone and most of the living chamber. The lateral diameter of the conch increases from 6 mm. at the base of the specimen to 13 mm. at the base of the living chamber, thence decreasing to 10 mm. at the aperture. The dorsoventral diameter increases from 13 mm., at a point 10 mm. beneath the lowest exposed part of the living chamber, to 15 mm. just above the base of the living chamber, where the conch is most gibbous, and then decreases to 13 mm. at the aperture. The lower 4 camerae have a total length of 5.5

mm. laterally, the following 4 camerae a total length of 6.5 mm., and the next 4 camerae a length of 7.5 mm. The uppermost camera is not quite half as long as the one immediately preceding, as might be expected at the gerontic stage of growth of the conch.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90919.

OXYGONIOCERAS Foerste

Genotype: *Trochoceras oxynotum* Barrande. Système silurien de centre de la Bohême, vol. 2, 91, pl. 14, figs. 1–11 (1867); *Oxygonioceras oxynotum* Foerste. Jour. Sci. Labs. Denison Univ., 21, 62 (1925); 21, 375, pl. 42, figs. 1 A–E (1926).

The genotype is characterized by its strong lengthwise curvature, lateral compression, and ovate outline, the dorsal part of its cross section being distinctly rounded while its ventral part is subangular. The sutures of the septa curve distinctly downward laterally and rise strongly in a ventrad direction resulting in subangular ventral saddles. The siphuncle is cyrtochoanitic in structure, the septal necks being very short, much smaller in diameter than the connecting rings, the latter being approximately globular but strongly truncated at top and bottom. The siphuncle is located close to the ventral side of the conch, but is not in contact with the latter. This genotype is from the Middle Silurian of Bohemia, now a part of Czechoslovakia.

The species described by Whiteaves under the name *Cyrtoceras cuneatum* (*24*), from the Silurian at Stonewall, Manitoba, has a similar cross section, but nothing is known of the structure of its siphuncle, and the latter was regarded by Whiteaves as located moderately ventrad of the center of the conch, which, if true, would not permit its reference to *Oxygonioceras*.

DIGENUOCERAS new genus

Genotype: *Oxygonioceras* (?) *latum* Foerste. Jour. Sci. Labs. Denison Univ., 24, 218, pl. 18, figs. 1, 2; pl. 19, fig. 2 (1929).

This genotype differs from typical *Oxygonioceras* in its cross

section, both the dorsal, as well as the ventral outline of the cross section being acutely angular. The segments of the siphuncle are subfusiform, rather than truncated globular on lateral view. From the lower or Dog Head member of the Red River formation from some unknown locality in Manitoba.

When this genotype was first studied the lenticular character of the cross section, with its acute margins both dorsally and ventrally, was noted; but the specimen evidently was compressed laterally, and it seemed at that time possible that the acuteness of the dorsal side of the cross section might be due to excessive lateral compression along this outline. However, among the specimens collected by T. E. Savage from the lower Big Horn on Medicine Mountain, in northern Wyoming, there is a similar specimen, consisting of limestone, in which the lenticular cross section is clearly preserved, with both dorsal and ventral margins acutely angular. It may be identical specifically with the genotype, but that is uncertain.

27. **Digenuoceras** cf. **latum** Foerste

Plate XIX, Fig. 5

Oxygonioceras (?) *latum* Foerste. Jour. Sci. Labs. Denison Univ., 24, 218, pl. 18, figs. 1, 2; pl. 19, fig. 2 (1929).

The specimen here figured is a fragment 54 mm. long, consisting of 7 camerae in a length of 37 mm. measured along its median lateral outline, the basal part of the living chamber being preserved for a length of 17 mm. The cross section of this conch is lenticular, with its dorsal and ventral ends acutely angular. Where its dorsoventral diameter is 63 mm. its lateral one is 26 mm. The conch evidently is curved lengthwise, since its upper 6 camerae occupy a total length of 38 mm. ventrally but only 20 mm. dorsally. The sutures of the septa curve downward 10 mm. laterally, their ventral saddles rising moderately higher than their dorsal ones. The concavity of the septa equals 2 or 3 mm. The siphuncle is about 3 mm. in diameter, its segments apparently enlarging only slightly within the camerae. Its distance from the ventral wall of the conch is about 2 mm.

Occurrence: Medicine Mountain, in the northeast corner of Big Horn county, Wyoming, about 13 miles south of Montana and 4 or 5 miles west of the Sheridan county line. From the basal part of the Big Horn formation. Collection of T. E. Savage.

WHITFIELDOCERAS Foerste

Genotype: *Oncoceras mumiaforme* Whitfield, Geol. Wisconsin, vol. 4, 232, pl. 7, figs. 3–5 (1882); Foerste, *Whitfieldoceras mumiaforme* (Whitfield), Jour. Sci. Labs. Denison Univ., 28, 60 (1933); 27, pl. 32, figs. 1 A, B, C; 2 A, B; 3: 4 (1932).

Conchs attenuate, faintly curved lengthwise, the ventral side distinctly convex along the top of the phragmacone and the base of the living chamber. Corresponding part of ventral outline faintly convex, the remainder of the conch, above and below this gibbous portion, faintly concave. Cross section circular or faintly depressed dorsoventrally. Siphuncle small, located slightly ventrad of the center of the conch; its segments moniliform.

Specimens of this type are known at present chiefly from the Trenton formation.

The specimen described by A. K. Miller under the name *Wetherbyoceras ? contractum* appears to be a typical specimen of *Whitfieldoceras.*

28. **Whitfieldoceras minimum** new species

Plate X, Fig. 5

The holotype is 14.5 mm. long, the living chamber occupying 8.25 mm. of this length. Its ventral outline has a radius of curvature in a convex direction of 30 mm. Its dorsal outline has a similar curvature along its gibbous part which includes both the lower part of the living chamber and the upper part of the phragmacone, but below this gibbous part the dorsal outline is assumed to have been slightly concave. The lateral diameter of the conch enlarges from 4.5 mm. at its base to 5.7 mm. at the base of the living chamber and then contracts to 4.5 mm. at a point 5.6 mm. above this second base, expanding to 5 mm. at the aperture. The

specimen is a cast of the interior of the conch and in this genus the contraction of the upper part of the cast of the interior of the living chamber is known to correspond to an annular thickening of the inner wall of this chamber. The conch is slightly depressed dorsoventrally, its dorsoventral diameter at the base of the living chamber, being 5.5 mm. Four camerae, still attached to the base of the living chamber, have lengths of 1.6 mm., 1.6 mm., 1.4 mm., and 1 mm. respectively. The sutures of the septa slope downward moderately in a ventral direction. The center of the siphuncle is 2 mm. from its dorsal wall where the dorsoventral diameter of the conch is 4.4 mm. The passage of this siphuncle through the siphuncle here is almost 0.5 mm. in diameter.

A second specimen, 16 mm. long, enlarges laterally from 4 mm. at its base to 5.2 mm. at a point 11 mm. farther up. The number of camerae in this length is 8 mm., the lower ones being only slightly shorter than the upper ones.

A third specimen, 24 mm. long, retains the lower part of the living chamber for a length of 5 mm. Its lateral diameter at the base of this chamber is 5.5 mm. The concave curvature of the dorsal outline of the phragmacone, for a length of 14 mm., has a radius of curvature of 60 mm.

A fourth specimen consists of a fragment of a phragmacone 6.5 mm. long, with a lateral diameter of 4.2 mm. at its top. There are 5 camerae within its length.

Occurrence: Elkador, Clayton county, Iowa; from the Asylum quarry just above the river road, in beds 2 feet thick 60 feet above the river level. From the *Catazyga uphami* zone at the top of the Prosser. U. S. National Museum, no. 90920.

29. **Whitfieldoceras contractum** Miller

Wetherbyoceras ? *contractum* A. K. Miller. The Cephalopods of the Big Horn Formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 287, pl. 28, fig. 3 (1932).

This is a typical specimen of *Whitfieldoceras*, a genus proposed after the publication of the monograph cited above. It closely resembles in size and general form the genotype, *Whitfieldoceras*

mumiaforme (Whitfield), from the Beloit or Platteville member of the Black River. The holotype was found in the basal sandstone of the Big Horn formation near the divide between Squaw Creek and the Middle Fork of Popo Agie River, about 8 miles west of Lander, Wyoming. Collection of Univ. of Missouri, no. 4590.

FAYETTOCERAS Foerste

Genotype: *Cyrtoceras thompsoni* Miller, 18th Ann. Rep. Indiana Dept. Geol. Nat. Res., 323, pl. 10, figs. 7, 8 (1894); Foerste, *Fayettoceras thompsoni*, Jour. Sci. Labs. Denison Univ., 28, 135 (1933); 27, pl. 31, figs. 6 A, B (1932).

Conchs moderately curved lengthwise, enlarging moderately, depressed dorsoventrally, with the siphuncle near the ventral wall of the conch; its segment oval, elongated vertically. Striae on the surface of the shell directly transverse as far as known. Genus not well known.

30. **Fayettoceras canyonense** new species

Plate XXII, Figs. 6, 7: plate XII, figs. 1, 2

The holotype consists of a fragment of a phragmacone about 32 mm. long. At its base its lateral diameter is 39 mm. and its dorsoventral one is 30 mm. At a point 20 mm. farther up these diameters are estimated at 45 mm. and 36 mm. There are 3 camerae and the lower part of a fourth camera. The 3 camerae have a total length of 20 mm. dorsally and of 23 mm. ventrally. The sutures of the septa slant moderately downward in a ventrad direction, the resulting ventral saddles being broad, shallow, and about 4 mm. deep. The concavity of the septum at the base of the specimen is 4 mm. The siphuncle has not been identified beyond doubt but its center appears to be located about 5 mm. from the ventral wall of the conch. The surface of the shell is distinctly banded in a transverse direction, 3 bands occurring in a length of 6 mm. The lower part of each band appears to invaginate into the top of the band next beneath, so that the upper outline of each band is distinctly defined. Owing to the downward slope of the sutures of the septa in a ventrad direction these sutures distinctly

cross the more directly transverse bands at a low angle. (Plate XXII, figs. 6, 7.)

Occurrence: Eight Mile Mountain, north of the Parkdale road, between 4 and 8 miles north of Canyon City, Fremont county Colorado. From basal part of Fremont formation. Collected by S. W. Loper. U. S. National Museum, no. 90921.

A second specimen, apparently belonging to the same species, was collected by C. D. Walcott at the Harding quarry, 2.5 miles northwest of Canyon City, in the basal part of the Fremont formation. It is 75 mm. long and the radius of curvature of its ventral outline is about 150 mm. Its dorsoventral diameter enlarges from 31 mm. at its base to 45 mm. at a point 50 mm. farther up. The corresponding lateral diameters are estimated at approximately 40 and 54 mm. The 3 camerae at the base of the specimen have a total length of 16 mm. ventrally. Apparently there are faint traces of 2 additional camerae in the overlying 10 mm. The sutures of the septa slope moderately downward in a ventrad direction. The concavity of the septum at its base is 7 mm. There is no trace of the siphuncle nor of transverse bands on the surface of the shell. U. S. National Museum, no. 90922. (Plate XII, Figs. 1, 2.)

TRIPTEROCERAS Hyatt

Genotype: *Orthoceras hastatum* Billings. Geol. Surv. Canada, Rep. Progress for 1853–56, 333 (1857); Foerste, Jour. Sci. Labs. Denison Univ., 20, 231, pl. 31, figs. 3 A, B, C, D (1924); 27, 131, pl. 13, fig. 8 (1932).

Conch strongly depressed dorsoventrally, strongly flattened ventrally, less flattened dorsally, usually faintly angulate along the median part of the dorsal side. Lateral angles of the cross section obscurely truncated or narrowly rounded; when truncated, the lateral sides tend to converge toward the dorsal side of the conch. Siphuncle small and located near the ventral side of the conch but not in contact with the latter.

The genotype of *Tripteroceras* is the species described by Billings under *Orthoceras hastatum*. That of *Allumettoceras* is *Tripteroceras paquettense* Foerste. Both are from the Black River at

Paquette Rapids on the Ottawa River, Canada. Both genotypes were figured and described by Foerste in his Notes on American Paleozoic Cephalopods, in the Journal of the Scientific Laboratories of Denison University, 20, 232 and 233, in 1924. The descriptions and citations of plates and figures on these pages are correct, but for some unaccountable reason the names are reversed in the description of plate 31. Here figures 3 A–D represent *Tripteroceras hastatum*, while figures 2 A–D represent *Tripteroceras paquettense*, later selected as the genotype of *Allumettoceras*. In the collections of the National Museum of Canada both species were found in the same tray, labelled *Orthoceras hastatum*, but there is no allusion to anything resembling *Allumettoceras paquettense* in the original description of *Tripteroceras hastatum* by Billings. When Hyatt (*25*), in his original description of the genus *Tripteroceras*, referred to its siphuncle as nummuloidal, he had the specimen used by Foerste as the type of *Allumettoceras paquettense* in mind. However, Hyatt definitely states that his genotype is the *Orthoceras hastatum* of Billings, which is an altogether different species, and Billings's original description of that species determines what forms he had in mind.

TRIPTEROCERINA new genus

Genotype: *Tripterocerina kirki Foerste.*

Conch differing from *Tripteroceras* chiefly in the coarse vertically ribbing of its dorsal side. Its ventral side is strongly flattened. Its lateral sides, though rounded, converge slightly in a dorsad direction. Its dorsal side is more strongly convex than its ventral one. The siphuncle is assumed to be located near the ventral side of the conch, but not in contact with the latter. The genotype is from the basal sandstone of the Big Horn formation in Wyoming.

31. Tripterocerina kirki new species

Plate XVIII, Figs. 2, 3

The holotype is 84 mm. long, 59 mm. of this length belonging to the living chamber. The chamber enlarges laterally from a diameter of 23.5 mm. at its base to 42 mm. at a point 47 mm.

farther up, its lateral vertical outlines being faintly convex. The corresponding dorsoventral diameters are 12 mm. and 20 mm., both the dorsal and ventral vertical outlines also being faintly convex. Evidently the rate of enlargement of the conch diminished at later stages of growth. Both the dorsal and ventral sides of the cross section have a radius of convex curvature of about 40 mm., that of the dorsal side being only slightly less. The lateral sides have a radius of transverse convexity of 7.5 mm., their width being about 10 or 11 mm. The suture of the septum at the base of the living chamber curves downward dorsally and ventrally about 5 mm., the dorsoventral concavity of this septum being slight. The location of the siphuncle is not known definitely, but is assumed to have been near the relatively smooth ventral side of the conch. The dorsal side of the living chamber is ribbed vertically, there being 7 low and broad ribs of which the median one is slightly narrower than the rest, the two lateral ones merging with the lateral walls of the conch. The surface of the specimen is crossed by faint transverse lines, 15 occurring in a length of 10 mm. These lines curve moderately upward both dorsally and ventrally.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90923.

GONIOCERAS Hall

Genotype: *Gonioceras anceps.* Hall. Pal. New York, vol. 1, 54, pl. 14, figs. 1 a–d (1847).

Conch straight, lenticular in cross section, with its ventral side much less convex or almost flat, compared with its dorsal one. The lateral thirds or wings terminate in sharp edges. The sutures of the septa curve strongly downward along the medium third of the conch, but arch strongly upward on crossing the lateral thirds or wings, curving strongly downward again on approaching the acute margins of the latter. The siphuncle is ventrad of the center of the conch but not in contact with the ventral wall. Its segments are low and nummuloidal, and their

interior is occupied by calcareous deposits similar to those of actinoceroids.

So far species of this type have not been found above the Black River formation.

LAMBEOCERAS Foerste

Genotype: *Gonioceras lambii* Whiteaves, Trans. Royal Soc. Canada, 9, pt. 4, 86, pl. 11, figs. 1 a, b (1892); Foerste, *Lambeoceras lambi*, Jour. Sci. Labs. Denison Univ., 24, 213, pl. 34, fig. 1; pl. 39, fig. 1 (1929).

Conchs, compared with *Gonioceras*, more nearly lenticular in cross section, with the ventral side almost as convex as the dorsal one. Lateral angles narrowly rounded in specimens as usually found, but acutely angular in *Lambeoceras acutilaterale* Foerste, in which the non-camerated lateral extension of the shell is preserved. Sutures of the septa curving strongly downward ventrally and dorsally along most of the width of the conch, but, on approaching the lateral margins of the conch they bend slightly outward. Siphuncle ventrad of the center of the conch, its segments nummuloidal. The septal necks curve strongly downward, the adjacent part of the upper side of the connecting rings being subparallel to these necks.

Species referable to this genus are not known at present below the level of the Stewartville and Big Horn formations. They range to the top of the Richmond formation.

32. Lambeoceras confertum Foerste

Plate VII, Figs. 1, 2

Tripteroceras lambi Clarke. Geol. Minnesota, vol. 3, pt. 2, 793, pl. 56, figs. 1, 2 (1897).

Lambeoceras cf. *lambi* Foerste. Three studies of cephalopods. Jour. Sci. Labs. Denison University, 24, 321, pl. 47, fig. 1 (1929).

Lambeoceras confertum Foerste. Black River and other cephalopods from Minnesota, Wisconsin, Michigan, and Ontario. Jour. Sci. Labs. Denison Univ., 27, pl. 24, fig. 2; 28, 42 (1932–33).

The specimen here figured is 120 mm. long, 71 mm. of this

length belonging to the living chamber. Its lateral diameter increases from 68 mm. at a point 50 mm. above its base to 89 mm. at the base of the living chamber which is 95 mm. farther up. The corresponding dorsoventral diameters are 26 mm. and 33 mm. At a lateral diameter of 81 mm. the radius of curvature of the ventral half of the cross section equals 110 mm., that of the dorsal half equalling 60 mm. The lateral angles of this cross section are rounded with a radius of 5 mm. Along the median line of the conch there are 12 camerae in a length of 85 mm. where that is also the lateral diameter of the conch at the top of the series counted. The sutures of the septa curve strongly downward both ventrally and dorsally. Where the lateral diameter is 72 mm. the sutures of the septa form broadly rounded lobes 28 mm. deep. At a diameter of 85 mm. these lobes are 30 mm. deep. Where the lateral diameter of the conch is 60 mm. a single nummuloidal segment of the siphuncle is exposed. This is 6 mm. long and 10 mm. in diameter. Its distance from the ventral wall of the conch is nearly 2 mm.

Occurrence: Half a mile west of Scales Mound, Jo Daviess county, Illinois, in a cut of the Illinois Central Railroad. From the Stewartville formation. Collected by Edwin Kirk. U. S. National Museum, no. 90924.

33. **Lambeoceras** cf. **confertum** Foerste

Plate VI, Fig. 2

The specimen here figured is 55 mm. long along the median line of its ventral side. The lateral diameter at its top is 82 mm., its dorsoventral diameter here equalling 33 mm. The lower 8 camerae occupy a length of 50 mm., the ninth or uppermost camera being only 4 mm. long, suggesting that the conch had attained its gerontic stage of growth. The downward curvature of the ventral lobes at the top of the specimen equals 25 mm. Through the uppermost septum the passage of the siphuncle is 4 mm. in diameter and its distance from the ventral wall is 6 mm. In the lower part of the second camera beneath the top of the conch the siphuncle is in contact with the ventral wall of the

conch. The entire segment at this point is estimated at 12 mm. in diameter.

The septum at the base of the specimen slopes downward in a ventrad direction medially, but in a dorsad direction along its lateral thirds. This assists in the orientation of specimens of the genus in which the siphuncle is not exposed.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90925.

Remarks.—This specimen is similar to typical *Lambeoceras confertum* Foerste in its rate of enlargement laterally, the length of its camerae, the depth of its ventral and dorsal lobes, and the diameter of its siphuncle. It differs chiefly in its greater dorsoventral diameter. Possibly this diameter is better preserved in the basal sandstone of the Big Horn than in the finegrained limestone of the Stewartville.

34. **Lambeoceras landerense** new species

Plate VI, fig. 1

The holotype is 140 mm. long and consists chiefly of the phragmacone, only the basal part of the living chamber being preserved. Its lateral diameter enlarges from 73 mm. at its base to 107 mm. at the top of the phragmacone. At a lateral diameter of 81 mm. the dorsoventral one is 31 mm. The radius of curvature of the ventral side of its cross section is 80 mm., that of its dorsal side being about 65 mm. The lateral angles are relatively blunt. Along the median part of its ventral side the lower 9 camerae occupy a length of 52 mm., that of the following 9 camerae being 48 mm. At a lateral diameter of 78 mm. the center of the siphuncle is about 7 mm. from the ventral wall of the conch. Here its passage through the septum is approximately 5 mm. in diameter. The segments of the siphuncle enlarge within the camerae into broad, low, and flat disks, which come in contact with the septa beneath over an area 13 mm. in diameter and extending to about 1 mm. from the ventral wall of the conch. Within the camerae

they probaby almost reach this wall. The dorsal side of the conch is crossed transversely by bands of approximately the same width, 5 bands occurring in a length of 17 mm. These bands are most distinct along the upper left corner of the dorsal side of the conch. They arch upward medially to a height of about 9 mm., crossing the downward curving sutures of the septa. As in other species of *Lambeoceras,* the median parts of the ventral lobes are more narrowly rounded along the lower part of the conch than farther up.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90926.

Remarks.—This species differs from typical *Lambeoceras cultratum* Miller chiefly in its greater dorsoventral diameter, the dorsal side of its cross section being more convex. Its lateral angles are more bluntly rounded. The diameter of the siphuncle is conspicuously greater and its center is farther from the ventral wall of the conch.

35. **Lambeoceras** cf. **cultratum** Miller

Plate II, Fig. 5

Tripteroceras lambi Trowbridge, A. C. and Shaw, E. W. Geology and Geography of the Galena and Elizabeth quadrangles. Bull. no. 26, Illinois Geol. Surv., pp. 40, 52; pl. 5, fig. 7 (1916).

Lambeoceras cultratum A. K. Miller. Trans. Connecticut Acad. Arts and Sciences, 31, 277, pl. 26, fig. 1; pl. 27, fig. 4 (1932).

The specimen is 57 mm. long and is 71 mm. wide at its top. It enlarges laterally at an angle of 8 degrees. The greater part of its dorsal side is not preserved but that part of its dorsolateral sides which remains suggests that its original dorsoventral diameter was approximately 27 mm. where the lateral one is 69 mm. At its lower end the radius of transverse curvature of its ventral side is 65 mm., while that of its dorsal side is estimated at 45 mm. Beneath the point where its lateral diameter is 72 mm. there are 7

camerae in a length of 34.5 mm. measured along their median part. The sutures of the septa here curve downward 20 mm. on the ventral side of the conch. Laterally the septa slant downward in a dorsad direction. The siphuncle is very close to the ventral side of the conch, the lower part of its segments being in actual contact with the ventral wall at the base of each camera, the contact areas being small and transversely elliptical.

Occurrence: Jo Daviess county, in the northwestern corner of Illinois; exact locality unknown. From the Stewartville formation. Included, in the publication cited above, in the top of the Galena formation as understood at that time. Museum of the University of Iowa, no. 700.

Remarks.—This specimen evidently is closely related to *Lambeoceras landerense* Foerste from the basal sandstone of the Big Horn formation in the Popo Agie River region of Wyoming, resembling it in the relative length of its camerae and in its thickness dorsoventrally, the dorsal side of the cross section being distinctly more convex than its ventral one. It differs in the smaller size of its siphuncle and in the location of the center of this siphuncle nearer the ventral wall of the conch.

36. **Lambeoceras acutilaterale** new species

Plate VI, Fig 3

The holotype is 70 mm. long, the median part of the ventral side of the living chamber being preserved for a length of 28 mm. Its lateral diameter increases from 39 mm. near its base to 55 mm. at a point 35 mm. farther up, indicating an angle of enlargement laterally of 27 degrees. This angle is much larger than in the other specimens described here but it is known that in the genus *Lambeoceras* the conch enlarges more rapidly at earlier stages of growth. The camerated part of the conch does not occupy the entire width of the latter. There is a lateral border, 3 or 4 mm. in width, within which there is no trace of cameration. Where the lateral diameter of the conch is 53 mm. that of the camerated part of the conch is 45 mm. Both the camerated part of the conch

and its noncamerated part are acutely angulate laterally, the angle of the noncamerated part being sharper. The length of the camerae enlarges rapidly from 3 in a length of 6 mm. at its base to 3 in a length of 12 mm. at its top. Where the lateral diameter of the camerated part of the conch is 47 mm. the depth of the ventral lobes of the sutures of the septa is 13 mm.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90927.

PARACTINOCERAS Hyatt

Genotype: *Sactoceras canadense* Whiteaves. Trans. Royal Soc. Canada, 9, sec. 4, 85, pl. 10, figs. 1 a–c (1892); *Paractinoceras canadense* Hyatt, Zittel-Eastman Textbook of Paleontology, p. 528 (1900); Foerste, Jour. Sci. Labs. Denison Univ., 24, 210, pl. 14, fig. 2; pl. 26, figs. 3 A, B (1929).

Conch slender, the long living chamber tapering toward the aperture; distinctly depressed dorsoventrally in its present condition. Sutures of the septa curving downward along the ventral side of the conch. Siphuncle located on the ventral side of the conch but not in contact with the latter. The septal necks are long, as in typical *Actinoceras*, and the lower connecting rings are relatively broad and nummuloidal, but farther up they become more nearly globular in form, and at the top of the phragmacone they are elongated vertically, enlarging only moderately within the camerae.

The genotype is from the lower or Dog Head member of the Red River formation, in southern Manitoba. Neither the specimen figured by A. K. Miller from the basal sandstone of the Big Horn formation in the area west of Lander, Wyoming, nor that figured here from the lower part of the Big Horn from Medicine Mountain, west of the northern part of the Big Horn Range in Wyoming, are known to have those changes in the form of the segments of the siphuncle with advancing age which are charac-

teristic of the genotype, but they are both closely similar in other respects, as far as their structure is known.

37. **Paractinoceras canadense** Whiteaves

Plate XI, Fig. 5

Sactoceras canadense Whiteaves. Trans. Royal Soc. Canada, 9, sec. 4, 85, pl. 10, figs. 1 A–C (1892).

Paractinoceras canadense Foerste. Denison Univ. Bull., Jour. Sci. Labs., 24, 210, pl. 14, fig. 2; pl. 26, figs. 3 A, B (1929).

Paractinoceras canadense A. K. Miller. Trans. Connecticut Acad. Arts and Sciences, 31, 265, pl. 21, fig. 4 (1932).

The holotype is 124 mm. long, 65 mm. of this length belonging to the living chamber. Its lateral diameter increases from 23 mm. near its base to 27.5 mm. at the base of the living chamber, which is 50 mm. farther up, and then diminishes gradually to 24 mm. The original cross section of the conch may have been circular, or nearly so, but in its present condition it is somewhat compressed along one of its ventrolateral sides. At a diameter of 26 mm., the 4 underlying camerae have a total length of 32 mm., the 2 overlying camerae having a total length of 13.5 mm., while the following 2 camerae are 4.5 mm. and 2.7 mm. in length respectively. Evidently the conch had attained its gerontic stage of growth. The sutures of the septa appear to have been directly transverse dorsally but to have curved downward ventrally about 3 or 4 mm. The concavity of the septa equals about 4 mm. Between the third and fourth camera above the base of the specimen the passage of the siphuncle through the septum equals 5 mm. in diameter and its distance from the ventral wall of the conch is 1.75 mm. The living chamber is relatively long. The surface of the shell is unknown, but judging from the cast of the interior of the conch it probably was smooth or faintly striated transversely.

Occurrence: Medicine Mountain, in the northeast corner of Big Horn county, Wyoming; about 13 miles south of Montana and 4 or 5 miles west of Sheridan county. From the basal part of the Big Horn formation. Collection of T. E. Savage.

KOCHOCERAS Troedsson

Genotype: *Kochoceras cuneiforme* Troedsson. On the middle and upper Ordovician faunas of northern Greenland, part 1, Cephalopods, p. 68, pl. 37, figs. 2–4; pl. 38, pl. 39, pl. 40, figs. 1, 2; pl. 44, fig. 6 (1926).

Conchs closely similar to *Actinoceras*, but the ventral side is strongly flattened, the lateral sides rounding rapidly into the much more broadly rounded dorsal side of the conch. The siphuncle is depressed dorsoventrally and is in flattened contact with the ventral wall of the conch. The contact areas on the connecting rings usually are broad and conspicuous; the septal necks being free from contact. Successive segments of the siphuncle usually diminish in diameter dorsoventrally, and even laterally.

Unfortunately the exact structure of the genotype of the closely related genus *Actinoceras* is inadequately known.

38. **Kochoceras grande** new species

Plate VIII, Fig. 1

The holotype is 340 mm. long and includes the lower part of the living chamber and the upper part of the phragmacone. Its lateral diameter enlarges from 131 mm., at a point 95 mm. beneath the top of the uppermost saddle on the left side of the specimen, as figured, to 149 mm. at a point 25 mm. above this saddle, indicating an angle of enlargement of 9 degrees laterally. The ventral side of the conch, at least in its present condition, is only slightly convex between the ventrolateral saddles. The cross section of the conch at the ventrolateral angles has a radius of curvature of 20 mm. for a width of 35 mm. The dorsal side is not exposed, but a dorsoventral diameter of 90 to 100 mm. at the top of the phragmacone is assumed from the amount of curvature here ventrolaterally. At the top of the phragmacone the lateral diameter of the conch is about 148 mm. The living chamber is preserved for a length of 115 mm. above the uppermost saddle on its left side. The radius of upward curvature of this saddle is 30 mm. Between the two saddles of the uppermost

septum the suture curves downward for a depth of 41 mm., the resulting ventral lobe having a radius of concave curvature of 45 mm. Eight camerae are preserved on the left side of the specimen. The lower 4 of these have a total length of 52 mm., while the overlying 4 measure only 37.5 mm., suggesting that the conch had attained its gerontic stage of growth. Along the median part of the phragmacone there are faint traces of low and broad transverse raised lines, 10 in a length of 15 mm. Their course laterally can not be determined.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90928.

WESTONOCERAS Foerste

Genotype: *Cyrtoceras manitobense* Whiteaves. Trans. Royal Soc. Canada, 7, sec. 4, 80, pl. 13, figs. 3–5; pl. 15, fig. 4 (1890); *Westonoceras manitobense* Foerste, Jour. Sci. Lab. Denison Univ., 20, 253 (1924); Contrib. Mus. Pal. Univ. Michigan, 3, 49, pl. 5, fig. 1; pl. 11, fig. 5 (1928); Jour. Sci. Labs. Denison Univ., 24, 220, pl. 38, figs. 2, 3 (1929).

Conchs curved lengthwise, with the ventral side convex, this convexity being accentuated at a hump 4 or 5 camerae beneath the base of the living chamber ventrally. A much smaller gibbosity is shown by the dorsal outline along the upper part of the phragmacone, a short distance beneath the living chamber; the lower part of the phragmacone and the upper part of the living chamber here tend to be faintly concave. The sutures of the septa curve downward laterally, the maximum depth of the resulting lobes being dorsad of the center of the conch. The ventral saddles rise higher than the dorsal ones and are distinctly subangular. The siphuncle is near, but not in contact with the ventral wall of the conch. Its segments are barrel-shaped, narrowing abruptly where near contact with the septa, with a narrow passage through the septa, their lateral sides being gently convex in vertical sections.

This genus includes *Thuleoceras* Troedsson (*26*), which is known only from the lower part of the phragmacone.

39. **Westonoceras deckeri** new species

Plate IV, Fig. 1

The holotype is 167 mm. long. Its ventral side has a radius of convex curvature of 300 mm. for a length of 95 mm., above which it decreases to 50 mm. for a length of 45 mm., as far as the base of the living chamber. Along this chamber the ventral outline is almost straight, its direction being a continuation of that directly beneath the base of the chamber. The dorsal outline has a radius of concave curvature of 80 mm. for a length of 42 mm., changing to 200 mm. along the following 44 mm., and then reversing to convex with a radius of 70 mm. for a length of 20 mm., where this outline reaches the base of the living chamber. Above this point it continues as far as the aperture in a direction closely similar to that followed just beneath this chamber. The dorsoventral diameter of the conch enlarges from 13 mm. at the base of the specimen to 61 mm. at its most gibbous part, which is located 4 or 5 camerae beneath the living chamber, and then decreases to 45 mm. at the aperture. The lateral diameter increases from 12 mm. at its base to 31 mm. at a point 53 mm. farther up; it is estimated at 57 mm. at the maximum gibbosity of the conch, and at approximately 40 mm. at the aperture. The margin of the aperture slopes strongly downward in a dorsad direction. At a diameter of the conch of 23 mm. the camerae in a corresponding length ventrally number 6; at 52 mm. their number is 9; at the maximum diameter of the conch 4 camerae occur in a length of 36 mm. Farther up the length of the camerae becomes successively shorter as far as the top of the phragmacone. At the base of the specimen the sutures of the septa curve only faintly downward laterally, and slope moderately downward in a ventrad direction. On approaching the more gibbous part of the conch their downward lateral curvature increases gradually, equalling 11 mm. along the upper part of the phragmacone, the maximum downward curvature being located dorsad of the middle of the lateral sides. The sutures in the mean time become first more nearly horizontal, but toward the top of the phragmacone, where their downward curvature laterally becomes conspicuous, the ventral saddles rise increasingly to higher levels

than the dorsal ones. Since the cross section of the conch is more narrowly rounded ventrally than dorsally, the ventral saddles are not only higher but also more angular than the low and broad dorsal ones. The cast of the interior of the conch is vertically ribbed, as in most other species of this genus.

Occurrence: West of Bromide, and east of the Large Quarry in section 31, township 1 south, and range 8 east. Near the top of the Viola formation. Collection of Prof. Charles E. Decker.

Another specimen, 138 mm. long, was found 5 miles northwest of Bromide, Oklahoma, in section 7, township 1 south, range 8 east.

Bromide is located in the northeast corner of Johnston county, 18 miles southwest of Coalgate, Oklahoma.

Remarks.—Compared with typical *Westonoceras minnesotense* (Clarke), from the Stewartville formation of Minnesota, the phragmacone of this Oklahoma species enlarges more rapidly, especially in a dorsoventral direction, as far as its maximum gibbosity, which is several camerae beneath its top. The hump along its ventral outline here is more angular, and hence more conspicuous. The dorsal outline tends to be faintly concave except along the upper part of the phagmacone where it is slightly gibbous.

DIESTOCERAS Foerste

Genotype: *Gomphoceras indianense* Miller and Faber. Jour. Cincinnati Soc. Nat. Hist., 17, 137, pl. 7, figs. 3–5 (1894); Foerste, Jour. Sci. Labs. Denison Univ., 20, 263, pl. 25, figs. 1 A, B; pl. 26, figs. 1 A, B, 2 A, B; pl. 27, fig. 2 (1924).

The genotype is a breviconic erect conch, moderately compressed laterally. The conch enlarges as far as the top of the phragmacone and then contracts along the living chamber toward the aperture. At the aperture the marginal part of the wall of the living chamber curves distinctly inward, in a horizontal direction, for a distance of 3 or 4 millimeters. The outline of this aperture tends to be oval, with its ventral side more narrowly rounded. This locates the ventral side of the conch. The vertical outline most distant from the siphuncle is slightly more

convex than that nearest the latter, and the total length of the camerae along this more convex side of the conch is greater than on its siphuncular side, the sutures of the upper septa tending to rise higher here. From this it is assumed that the affinity of the genus *Diestoceras* is with that of endogastric conchs. The siphuncle appears to be nummuloidal, and is near the dorsal wall of the conch but not in actual contact with the latter. The surface of the shell is striated transversely, these striae curving downward on the ventral side of the conch, thus locating former positions of the hyponomic sinus.

A similar moderate incurvature of the lateral walls of the living chamber at the aperture is noted in *Diestoceras fremontense*, here described. In other specimens it sometimes is much more conspicuous; for instance in *Diestoceras arenicolum* (*27*) from Anticosti, *Diestoceras whiteavesii* (*28*) from Manitoba, and *Diestoceras staufferi* (*29*) from Minnesota. In *Diestoceras magister*, described here, it is still more in evidence.

The species most nearly resembling *Diestoceras fremontense* in their size, lateral compression, rate of elongation, and cameration are *Diestoceras tyrrelli* (Parks) (*30*) from the Hudson Bay area; *Diestoceras vagum* Foerste, *Diestoceras carletonense* Foerste, and *Diestoceras anticostiense* Foerste, all three (*31*) from Anticosti; and *Diestoceras clarkei* Foerste (*32*) from Minnesota.

The species most nearly resembling *Diestoceras walcotti*, here described, in its slender proportions, is *Diestoceras alceum* (Hall) (*33*) from Wisconsin.

The species most nearly resembling *Diestoceras occidentale*, here described, in its small size, subglobular form of the conch and its deeply concave septa is *Diestoceras schucherti* Foerste (*34*) from the Baffin Land area. In *Diestoceras curtum* the upper part of the conch is even more rotund, but the septa are only moderately concave, and the lower part of the dorsal outline is faintly concave.

40. **Diestoceras magister** new species

Plate IX, Fig. 1; Plate X, Fig. 1

The holotype is 195 mm. long, 92 mm. of this length belonging to the living chamber. In its present flattened condition the

maximum lateral diameter enlarges from 97 mm. at its base to 152 mm. at the base of the living chamber, and to 167 mm. at a point 45 mm. above the base of this chamber. From this point it contracts to 143 mm. where almost up to the level of the aperture, and then contracts rapidly to 117 mm. at the aperture itself. Along the phragmacone there is little lengthwise curvature laterally. Along almost all of the living chamber the radius of curvature of its lateral sides is 130 mm., except toward its top where it first shortens to 80 mm. and then abruptly to 30 mm. on curving more strongly inward toward the aperture. The lower 4 camerae have a total length of 58 mm., increasing consecutively from 11 mm. to 17 mm. in this length. The following three occupy a total length of 35 mm., decreasing consecutively from 15 or 16 mm. to 8 or 9. The siphuncle is not exposed. (Plate IX, Fig. 1.) U. S. National Museum, no. 90929.

A second specimen consists only of the living chamber, probably not including its lower part. This specimen is 90 mm. in height. Its maximum lateral diameter is 172 mm., its minimum being almost the same. Near the top of the chamber, where its walls begin to curve rapidly inward, its maximum diameter is 165 mm., diminishing rapidly to 105 mm. at the aperture, the marginal part of the conch here curving inward for a width of 10 mm. and a depth of 3 or 4 mm., the thickness of the shell at the border being 3 or 4 mm. One side of the aperture is more narrowly rounded, suggesting a hyponomic sinus. U. S. National Museum, no. 90930-B.

A third specimen preserves only the upper half of the living chamber, for a height of 78 mm. Its maximum diameter is 170 mm., its minimum one being almost the same. At the point where its walls curve strongly inward its maximum diameter is 155 mm., contracting to 110 mm. at the aperture. That part near the aperture, for a width of 9 to 15 mm. curves downward from 2 to 3 mm. The outline of the aperture is subtriangular, but it is impossible to orient the angles owing to the absence of any trace of the siphuncle. U. S. National Museum, no. 90930-A. (Plate X, Fig. 1.)

Occurrence: South side of Middle Fork of Popo Agie river, 8

miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, nos. 90929, 90930-A, B.

41. **Diestoceras cf. landerense** Miller

Plate XI, Fig. 1

Diestoceras landerense A. K. Miller. Trans. Connecticut Acad. Arts and Sciences, 31, 290, pl. 28, fig. 7 (1932).

The holotype is 121 mm. long. Judging by its cross sections at different levels this specimen enlarges in diameter from 60 mm. at its base to 90 mm. at the base of the living chamber and then contracts to 70 mm. at the aperture, the lower interval being 50 mm. and the upper one 47 mm. There are 5 camerae in a total length of 58 mm. The lowest camera is almost 9 mm. long, the following ones varying between 11 and 13 mm. The sutures of the septa are almost directly transverse. The specimen is a cast of the interior of the conch. Its surface is crossed transversely by low and broad annulations, about 10 annulations in a length of 20 mm. These cross the sutures of the septa at an angle of about 5 degrees. There are also low vertical ribs, about 5 in a width of 18 mm. Unfortunately there is no trace of the siphuncle and at present it is not possible to determine how the specimen should be oriented. Its most characteristic features are its erect growth, the tallness of its camerae, and the subangular change in direction of its vertical outlines at the base of the living chamber.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90931.

42. **Diestoceras fremontense** new species

Plate XI, Fig. 3

The holotype is 70 mm. long, 31 mm. of this length belonging to the living chamber. The most convex vertical outline is assumed to be ventral. Here the radius of curvature is 130 mm. along the living chamber and most of the phragmacone, shortening

to 35 mm. at their junction. The corresponding radius of the dorsal outline is 100 mm. along the phragmacone, shortens to 60 mm. along the lower part of the living chamber, and reverses to slightly concave farther up. The dorsoventral diameter of the conch increases from 30 mm. at its base to 50 mm. at the base of the living chamber and then shortens to 43 mm. at its top. The corresponding lateral diameters are 25 mm., 41 mm., and 34 mm. There are 7 camerae in a length of 30 mm. laterally, the uppermost one being only 3 mm. long. The sutures of the septa are straight. The concavity of the septum at its base is 6 or 7 mm. There is no trace of the siphuncle.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90932.

Remarks.—This specimen is distinguished from the type of *Diestoceras kirki* Foerste by its greater dorsoventral diameter, compared with its lateral one, by the greater convexity of its ventral outline, and by the location of its maximum ventral convexity at the junction of the phragmacone and the living chamber.

43. **Diestoceras kirki** new species

Plate XI, Fig. 2

The holotype is distinguished from that of *Diestoceras fremontense* Foerste chiefly by its shorter dorsoventral diameter, compared with its lateral one, and the location of its maximum dorsoventral diameter at a point 10 mm. above the base of the living chamber, instead of at this base.

The conch is 65 mm. long, 27 mm. of this length belonging to the living chamber. The most curved vertical outline is assumed to be ventral. The radius of curvature of this outline is 150 mm. along the phragmacone, shortening to 35 mm. along the living chamber. The dorsal outline is nearly straight along the lower half of the phragmacone, changing to a radius of convex curvature of 50 mm. along the upper half of the phragmacone and the lower

half of the living chamber, and reversing to faintly concave farther up. The dorsoventral diameter of the conch enlarges from 22.5 mm. at its base to 45.6 mm. at a point 10 mm. above the base of the living chamber, and then shortens to 39 mm. at its top. The corresponding lateral diameters are 19.5 mm., 40 mm., and approximately 36 mm. Seven camerae occur in a length of 33.5 mm. laterally. The sutures of the septa are straight and directly transverse.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. From the basal sandstone of the Big Horn formation. U. S. National Museum, no. 90933.

Remarks.—*Diestoceras kirki* differs from *Dowlingoceras ornatum* A. K. Miller (*35*), here regarded as a *Diestoceras,* in its relatively greater dorsoventral diameter and in the location of its maximum dorsoventral diameter distinctly above the base of the living chamber ventrally. The subannular enlargement of the upper part of the living chamber, a short distance beneath the aperture, may be a pathologic feature, confined to a single individual. At a dorsoventral diameter of the conch of 30 mm. the segments of the siphuncle are subglobular in form, are 4 mm. in diameter, and are 2 mm. from the ventral wall of the conch. In typical *Dowlingoceras* (*36*) these segments enlarge but moderately within the camerae, being more nearly fusiform.

44. **Diestoceras walcotti** new species

Plate XII, Figs. 7, 8, 9

The specimen here figured is 57 mm. long, 25 mm. of this length belonging to the living chamber. Its dorsoventral diameter enlarges from 19 mm. at its base to 28 mm. at the base of the living chamber and to 29 mm. at a point 10 mm. above this base, and then decreases to 27 mm. at the aperture. The corresponding lateral diameters are 15 mm., 23 mm., 24 mm., and 21 mm. There are 11 camerae in a length of 31 mm., the lower 4 having a length of 9 mm., the next 3 a length of 8 mm., the next 3 a length of 12 mm., and the uppermost one a length of 2 mm. The sutures

of the septa curve slightly downward laterally, the uppermost one a distance of 1.5 mm. The concavity of the lowest septum is 3.5 mm. The siphuncle is exposed distinctly on the less convex outline of the conch.

Occurrence: Two and a half miles northwest of Canyon City, Colorado, at the Harding quarry. From the basal part of the Fremont formation, between 3 and 10 feet above the fish beds at the Harding sandstone, the latter being regarded as of Black River age. Collected by C. D. Walcott. U. S. National Museum, no. 90934.

45. **Diestoceras occidentale** new species

Plate XII, Figs. 3, 4; 5, 6; Plate XXII, fig. 8

The holotype is 40 mm. long, 22 mm. of this length belonging to the living chamber. The dorsoventral diameter at the base of this chamber is 50 mm., its lateral one here being 44 mm. The corresponding diameters at its upper end are 37 mm. and 30 mm. respectively. The margin of the aperture curves inward for a width of 2 or 3 mm. The outline of this aperture is oval, with its supposed ventral side more rapidly rounded. Three camerae remain attached. As far as can be determined in their present condition of preservation, their length in descending order is 2 mm., 4.5 mm., and 7 mm. approximately. The septum at its base has a concavity of at least 7 or 8 mm. U. S. National Museum, no. 90935. (Plate XII, figs. 3, 4; plate XXII, fig. 8.)

A second specimen found at the same locality, is represented by the lower half of the living chamber and by a separated fragment belonging to the phragmacone. At the lower end of the living chamber its dorsoventral diameter is 46 mm. and its lateral one is 44 mm. The phragmacone is preserved for a length of 25 mm. The septum at its base is strongly concave, its vertical section presenting a radius of curvature of 15 mm. for a width of 30 mm., above which the lateral outlines of the phragmacone diverge at an angle of about 45 degrees. U. S. National Museum, no. 90936. (Plate XII, figs. 5, 6.)

Occurrence: Two and a half miles northwest of Canyon City,

Colorado, at the Harding quarry. From the basal part of the Fremont formation. Collected by C. D. Walcott. U. S. National Museum, nos. 90935, 90936.

Remarks.—Compared with *Diestoceras schucherti* Foerste (*37*), the camerae of the Colorado species are relatively longer.

46. **Diestoceras curtum** new species

Plate XX, Fig. 5

The holotype is 62 mm. long, the living chamber occupying 27 mm. of this length. That outline here assumed to be dorsal has a radius of concave curvature of 50 mm. for a length of 15 mm. at its lower end, reversing to convex with a radius of 40 mm. as far as the aperture. The opposite outline, assumed to be ventral, is nearly straight for a length of 25 mm., its upper part evidently changing to convex as on the dorsal side of the conch. The dorsal outline of the phragmacone is 28 mm. long, its ventral outline being estimated at 40 mm. The dorsoventral diameter of the conch increases from 23 mm. at its base to approximately 54 mm. at the base of the living chamber. The lateral diameter increases from 23 mm. at its base to 51 mm. at the base of the living chamber. The cross section of the conch is circular at its base but is slightly compressed at its top. The maximum diameter of the conch is located 5 to 7 mm. above the base of the living chamber and is only slightly greater than at this base. The length of the camerae increases in the direction here called ventrad. Along the dorsal side of the conch there are 7 camerae in a length of 28 mm. At a diameter of 30 mm. the concavity of the septum is 4 or 5 mm. The siphuncle apparently is located near the side here called dorsal, its center being about 3 mm. from the latter. Its passage through the septum at its base is 2 mm. in diameter.

Occurrence: South side of Middle Fork of Popo Agie River; 8 miles west of Lander, Wyoming. From the Basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90937.

Remarks.—The most characteristic features of this conch are the relatively globose appearance of the living chamber and the

adjacent part of the phragmacone, and the slight concavity of that part of its ventral outline which is nearest the siphuncle, its structure being endogastric.

Diestoceras curtum possibly is related to the specimen described by A. K. Miller as *Cyrtogomphoceras angustisiphonatum* (*38*). This is suggested by the relatively rapid rate of enlargement of the latter, the small height of its camerae, the small diameter of the siphuncle both at its passage through the septum and at midheight within the camerae. Unfortunately the exact form of the segments of the siphuncle of *Diestoceras curtum* is unknown, and the same is true of the general form of the conch of Miller's species.

LANDEROCERAS new genus

Genotype: *Diestoceras prolatum* A. K. Miller. The cephalopods of the Big Horn formation of the Wind River mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 291, pl. 28, fig. 8 (1932).

Compared with typical *Diestoceras* these conchs are more elongate and attain their greatest diameters at a distance of several camerae beneath the living chamber, contracting thence as far as the aperture. The side most distant from the siphuncle is distinctly more convex than that nearest. In analogy with *Diestoceras,* this more convex side is regarded as ventral, and the location of the siphuncle as endogastric. The sutures of the septa are directly transverse ventrally and laterally, but curve more or less distinctly downward dorsally. The segments of the siphuncle are nummuloidal, and are distinctly and broadly flattened where in contact with the dorsal wall of the conch.

47. Landeroceras prolatum (Miller)

Plate V, Figs. 6, 7

Diestoceras prolatum A. K. Miller. The Cephalopods of the Bighorn formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 291, pl. 28, fig. 8 (1932).

The larger specimen figured here is 185 mm. long, 51 mm. of this length belonging to the living chamber. The conch is erect. Its lateral diameter enlarges from 51 mm. at a point 26 mm. above its base to 78 mm. at a point 77 mm. farther up, and then diminishes to 70 mm. at the base of the living chamber, and to approximately 50 mm. at the aperture. The conch is slightly depressed dorsoventrally, at least in its present state. At the maximum diameter of the conch the radius of curvature of its cross section decreases from 40 mm. ventrally to 35 mm. laterally. The dorsal part of the conch is not preserved, but at its maximum lateral diameter of 77 mm. the dorsoventral one is estimated at 74 mm. The lower third of the lateral outlines is only faintly convex; farther up its radius of curvature lengthwise equals 200 mm. This is true also of the ventral and dorsal outlines. The lowest 5 camerae occupy a total length of 25 mm.; the following one a length of 8 mm.; the following 4 a total length of 45 mm.; the next 3 a total length of 31 mm.; the next 2 a total length of 16 mm., the next camera a length of 6 mm., and the uppermost one a length of 3 mm. The sutures of the septa curve slightly downward ventrally. On its left lateral side they rise in a dorsad direction, while on its right side they are more nearly horizontal. The segments of the siphuncle are in flattened contact with the ventral wall of the conch, especially along midlength of the phragmacone. The areas of contact arch strongly upward from the suture of the underlying septa. The segments of the siphuncle evidently are nummuloidal. Where the lateral diameter of the conch is 56 mm., one segment of the siphuncle has a lateral diameter of 18 mm., its septal neck is 7 mm. in diameter and only slightly more than half a millimeter in length, and the center of this neck is about 5.5 mm. from the ventral wall of the conch. The cast of the interior of the conch is ribbed vertically, especially along the lower part of the lateral sides of the phragmacone. At the base of the living chamber there are two shallow grooves with a total vertical width of 5 mm., the lower one being occupied by shallow pits of about equal size, 5 occurring in a width of 21 mm. These are regarded as corresponding to the annular attachment areas occurring at the base of the living chamber of many gom-

phoceroids. U. S. National Museum, no. 90938-A. Plate V, fig. 6.

A second specimen consists of a living chamber 45 mm. long, to which the upper part of a phragmacone 80 mm. long is attached. The ventrolateral parts of the upper 3 sutures of the septa curve downward in an abnormal manner, possibly owing to the presence of some commensal animal living in the marginal part of the interior of the living chamber at late stages of growth. Similar decurrent sutures are noted not infrequently in other curved conchs (*39*). At the base of the specimen, where its obliquely dorsoventral diameter is 82 mm., the lateral diameter of the siphuncle is 24 mm. and the passage of this siphuncle through the septum is 3 mm. from the ventral wall of the conch. The diameter of this passage here is not known definitely, but is estimated at 9 or 10 mm. U. S. National Museum, no. 90938-B.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, nos. 90938-A, B.

Remarks.—This species appears to include also that specimen represented by fig. 3 on plate XXIX, published by A. K. Miller under the name *Diestoceras flexisutile*. Apparently it is this second specimen which furnished most of the data regarding the siphuncle in the description of that species.

The holotype of *Diestoceras flexisutile* Miller, on the contrary, does not expose the siphuncle on the ventral side of the cast of its interior, and is regarded as distinct generically from *Landeroceras*.

CYRTOGOMPHOCERAS Foerste

Genotype: *Oncoceras magnum* Whiteaves. Trans. Royal Soc. Canada, 7, sec. 4, 79, pl. 15, fig. 1 (1890); Foerste, Contrib. Mus. Pal. Univ. Michigan, 3, 59, pl. 6, fig. 1 (1928).

Conchs with convex ventral outline, the dorsal outline being slightly gibbous along the top of the phragmacone and the lower part of the living chamber, but more or less distinctly concave along the upper part of the living chamber and the lower part of the phragmacone. The sutures of the septa are nearly directly

transverse to the curving vertical axis of the conch along the lower part of the phragmacone but rise at an increasing angle toward the upper part of the phragmacone, this rise becoming conspicuous near the base of the living chamber. This chamber tapers conspicuously toward its aperture, the margin of the aperture sloping conspicuously downward in a ventrad direction, being approximately parallel to the uppermost sutures of the septa. Surface of shell with coarse transverse raised lines which slope downward toward the more convex side of the conch, showing that the latter is to be regarded as ventral, notwithstanding the slope of the aperture at gerontic stages of growth. The siphuncle is located near, but not in contact with the dorsal side of the conch, its location being endogastric. The segments of the conch are nummuloidal, low and broad, but not in contact with the adjacent wall of the conch.

Among the species described here, *Cyrtogomphoceras perexpansum* is much larger than any other species of this genus known. Compared with *Cyrtogomphoceras magnum* (Whiteaves) from southern Manitoba, the ventral outline of *Cyrtogomphoceras landerense* is less strongly curved, especially along the more gibbous part of the conch. Compared with *Cyrtogomphoceras landerense,* the conch of *Cyrtogomphoceras popoagiense* enlarges less rapidly, especially dorsoventrally, the upper part of the ventral outline of its phragmacone being less humped than in any other species known. In the holotype of *Cyrtogomphoceras rotundum* Miller (*40*) there is a moderate humping of the ventral outline at the fourth camera beneath the living chamber. In *Cyrtogomphoceras vicinum* the ventral outline is more evenly convex and the camerae, especially the lower ones, are distinctly longer.

The living chamber described here as *Cyrtogomphoceras contractum* is intermediate in size between that of *Cyrtogomphoceras landerense* and that of *Cyrtogomphoceras popoagiense,* but it contracts more rapidly toward the aperture. The living chamber here described as *Cyrtogomphoceras minor* resembles that of *Cyrtogomphoceras whiteavesi* (Miller) (*41*) in size but it contracts less rapidly toward the aperture.

The genus ranges as far north as Kane Basin, on the northwestern coast of Greenland.

48. **Cyrtogomphoceras perexpansum** new species

Plate XIII, Fig. 1

The holotype is 180 mm. long as far as the base of the living chamber along its convex ventral outline. If the missing basal part of the phragmacone is estimated at 70 mm. and the height of the living chamber at 100 mm. the original total length of the conch would be approximately 330 to 350 mm. This holotype is the largest specimen of the genus *Cyrtogomphoceras* found so far. It presents chiefly the dorsal and lateral sides of the conch though approaching close to its original ventral outline. This ventral outline was only slightly concave along the lower 120 mm. of its length, the convexity increasing to a radius of 200 mm. as far as the top of the phragmacone, only the basal part of the living chamber being preserved here. The lower part of the dorsal outline (on the siphuncular side of the conch) is concave with a radius of curvature of 120 mm. for a length of 52 mm. Above this point the dorsal curvature reverses to convex with a radius of 110 mm. for a length of 55 mm., the latter terminating at the top of the phragmacone. The lateral outline on the right side of the conch, as figured, is slightly concave with a radius of about 400 mm. for a length of 55 mm. and then reverses to convex with a radius of 120 mm. as far as the base of the living chamber, which is 90 mm. farther up. Above this point the dorsal convex curvature continues for a length of 55 mm., the top of the living chamber not being preserved. The lateral diameter of the conch enlarges from 58 mm. at its base to 140 mm. at a point 35 mm. below the living chamber along the middle of its lateral side. The maximum dorsoventral diameter at the top of the phragmacone is estimated at 175 mm. This maximum dorsoventral diameter is located at the base of the living chamber or just beneath the latter. The length of the camerae enlarges considerably in a ventrad direction, equalling 10 mm. at the base of the specimen and increasing to 17 mm. between 75 and 125 mm. farther up, then

gradually decreasing toward the top of the phragmacone, this upper interval being 65 mm. The downward curvature of the sutures of the septa is slight. The siphuncle is not exposed.

Occurrence: South side of Middle Fork of the Popo Agie River, 8 miles west of Lander, Wyoming. In the basal part of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90939.

49. **Cyrtogomphoceras landerense** new species

Plate XV, Fig. 5

The holotype is 158 mm. long and consists of the living chamber with 9 camerae still preserved along its ventral outline. The radius of curvature of this ventral outline is 130 mm. The dorsal (siphonal) outline is not exposed well but its radius of convex curvature is 90 mm. along the phragmacone and the lower part of the living chamber, reversing to concave with a radius of curvature of 60 mm. along the greater part of the living chamber. At the maximum gibbosity of the conch dorsally the dorsoventral diameter of the latter equals 100 mm., with a lateral one of 83 mm. At the aperture these dimensions are about 64 mm. and 56 mm. respectively. The height of the living chamber is 60 mm. dorsally and about 44 mm. ventrally. Along the ventral outline of the conch the lowest camera has a length of about 15 mm. increasing to 17 mm. along the six overlying camerae, and then diminishing to 13 mm. and 10 mm. at the upper 2 camerae. Dorsally these camerae are much shorter resulting in a rapid change of slope of the sutures of the septa, the latter rising only moderately in a ventrad direction at the base of the specimen but conspicuously so farther up, this rise equalling 50 degrees above the horizontal at the uppermost septum. The downward curvature of the sutures of the septa laterally is small. The concavity of the lowest septum exposed is 12 mm. Where the dorsoventral diameter of the conch is 85 mm. that of the siphuncle is 28 mm. its distance from the dorsal wall of the conch being 1 mm. or only slightly greater.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of

the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90940.

50. **Cyrtogomphoceras popoagiense** new species

Plate XIV, Figs. 3, 4

The holotype is 150 mm. long and includes the lower part of the living chamber for a length of 32 mm. and 137 mm. of the length of the phragmacone when measured along its ventral outline. The lower part of this outline, for a length of 95 mm., has a radius of curvature of 120 mm., changing to 100 mm. farther up. The dorsal outline is slightly concave along the lower part of the phragmacone and along the living chamber, but the upper part of the phragmacone is faintly convex. At the base of the specimen its cross section is circular, having a diameter of 34 mm., but at the maximum diameter of the conch its lateral diameter is 74 mm. and its dorsoventral one is 66 mm., while at the top of that part of the living chamber preserved these dimensions are approximately 59 mm. and 49 mm. Along the ventral outline of the conch the three lower camerae occupy a total length of 22 mm., increasing to 3 camerae in a length of 32 mm. at the maximum diameter of the conch, and then decreasing in length so that the uppermost camera measures only 8 mm. in this direction. The sutures of the septa are almost straight, except at the top of the phragmacone where they curve gently downward laterally. At the lower end of the specimen they slope gently downward in a ventrad direction, but soon become horizontal and above this level they rise at an increasing rate until at the top of the phragmacone they form an angle of 50 degrees with the horizontal ventrally. The passage of the siphuncle through the septum at the base of the specimen is 8 mm. in diameter, its center being 8 mm. from the dorsal wall of the conch. U. S. National Museum, no. 90941. (Plate XIV, fig. 3.)

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, nos. 90941, 90942.

Remarks: This species is represented by 3 specimens, all

slightly depressed dorsoventrally. It is relatively erect, and enlarges at a moderate rate compared with most other species of the genus.

51. **Cyrtogomphoceras rotundum** Miller

Plate XIV, Fig. 1

Cyrtogomphoceras rotundum A. K. Miller. The Cephalopods of the Big Horn formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 274, pl. 30, fig. 1; pl. 31, fig. 1 (1932).

The holotype, figured by A. K. Miller in the publication cited above, is characterized by the distinct angulation of the ventral outline of the conch at a point about 4 camerae beneath the living chamber, those parts of the outline above and beneath this point being distinctly less curved. The lower part of the phragmacone enlarges rapidly in a dorsoventral direction. It is probable that most species of *Cyrtogomphoceras* originally were approximately circular in cross section, but they often become more or less compressed or depressed after the death of the animal, especially when imbedded in sandstones.

Similar specimens occur in the U. S. National Museum, the one here figured being slightly more angular ventrally than in the holotype figured by A. K. Miller.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90943.

52. **Cyrtogomphoceras vicinum** new species

Plate XIV, Fig. 2

Associated with typical specimens of *Cyrtogomphoceras rotundum* Miller is a single specimen of similar size in which the maximum dorsoventral diameter is 71 mm. and the lateral one equals 66 mm. It differs in having an evenly convex ventral outline, with a radius of 60 mm. along the entire length of the phragmacone, as far as preserved, this length being 90 mm. Along the

living chamber this radius enlarges to 100 mm. Apparently the conch enlarges much more rapidly at its lower end than the species named above. The camerae are relatively a little longer ventrally. Along the lower part of the ventrolateral side of the conch the shell is marked by low and relatively numerous ribs or annulations, about 6 in a length of 12 mm., which slant downward in a ventrad direction at an angle of 15 degrees with the horizontal. From this it is evident that at earlier stages of growth of the conch the hyponomic sinus was relatively deep and wide, its location being on the convex side of the conch.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90944.

Remarks: This species evidently is closely similar to *Cyrtogomphoceras rotundum,* the chief differences consist in the more rapid enlargement of the lower part of the phragmacone, the more evenly rounded ventral outline, and the slightly greater length of the camerae ventrally.

53. **Cyrtogomphoceras contractum** new species

Plate XV, Figs. 1, 2, 3

Only a single living chamber of the type here figured was found. At its base its dorsoventral diameter is 78 mm. and its lateral one is 72 mm. The concavity of the septum here is 18 mm. The suture of this septum curves downward laterally about 7 mm. and rises distinctly toward the ventral side of the conch. The ventral outline is 55 mm. long and has a radius of convex curvature of 50 mm. at its base, changing to 110 mm. along its middle and upper part. The dorsal outline is 43 mm. long and changes from moderately convex at its base to moderately concave farther up. At the aperture its dorsoventral diameter is 45 mm. and its lateral one is nearly the same. The margin of the aperture appears almost straight on lateral view and it approaches the suture of the septum at the base of the chamber at an angle of 20 degrees in a dorsad direction. A fragment of the uppermost segment of

the siphuncle is attached to the dorsal side of its base. This segment was approximately 21 mm. in diameter and located near the dorsal wall of the conch.

Occurrence: Eight Mile Mountain, north of the Parkdale road, 4 and 8 miles north of Canyon City, Fremont county, Colorado. From the basal part of the Fremont formation. Collected by S. W. Loper. U. S. National Museum, no. 90945.

Remarks.—This living chamber is characterized by its great contraction toward the aperture, which is more conspicuous than in any other species known.

54. **Cyrtogomphoceras minor** new species

Plate XV, Fig. 4

The single living chamber here figured is relatively small. At its base its dorsoventral diameter is 51 mm. and its lateral one is 50 mm., but its cross section is perceptibly flattened ventrally and more narrowly rounded dorsally. The dorsal outline is 37 mm. long and its ventral one is 28 mm. The margin of the aperture appears straight on lateral view and slopes toward the suture of the septum at its base at an angle of 7 degrees in a ventrad direction. The dorsoventral diameter of the aperture is 35 mm. and its lateral diameter is 33 mm. but here again the ventral side of the cross section is flattened and the dorsal part is curved more rapidly, both to a greater degree than at the base of the chamber. The suture of the septum at the base of the chamber curves downward 2 mm. laterally. When the chamber is oriented as in other specimens of this genus, the suture of the septum at its base rises strongly in a ventrad direction, but not as strongly as in most other species. The ventral outline of the chamber is almost straight except at the broad shallow annular groove which surrounds the upper part of the cast of the interior of the chamber between 5 and 13 or 15 mm. beneath the margin of its aperture. The dorsal outline has a radius of convex curvature of 60 mm. beneath this groove. The groove evidently indicates the presence of an annular thickening of the interior of the shell at a corresponding height within the upper part of the interior of

the chamber. At the base of this chamber there is an annular attachment groove 3 mm. in height vertically, with shallow pits at the rate of 5 in a width of 15 mm. The ventral half of the septum at its base is smooth. The siphuncle is assumed to have been located on the side here called dorsal, as in other specimens of this genus.

Occurrence: South side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90946.

WILSONOCERAS Foerste

Genotype: *Trochoceras mccharlesi* Whiteaves. Trans. Royal Soc. Canada, 7, sec. 4, 81, pl. 16, figs. 1, 2 (1889); *Wilsonoceras mccharlesi* Foerste, Jour. Sci. Labs. Denison Univ., 24, 180, pl. 19, fig. 1, pl. 20, fig. 1; pl. 23, fig. 1 (1929); 29, 191, pl. 42, fig. 1 (1934).

Conchs frequently gyroceraconic, occasionally successive volutions are in light contact with each other locally, sometimes resulting in a faint depressed area along the median part of the dorsal side of the conch, but never with a distinctly marked impressed zone. Laterally the sutures of the septa are nearly straight or curve only faintly downward, but ventrally they form deep wide lobes. The siphuncle is located dorsad of the center of the conch. Its segments vary from almost globular to distinctly nummuloidal, the septal necks being relatively long. The surface of the shell is ornamented by relatively numerous transverse ribs, which are distinctly but not conspicuously elevated, and which curve downward in a ventrad direction at an increasing rate, indicating that the hyponomic sinus was broad and deep.

55. **Wilsonoceras bighornense** Miller

Plate XVI, Fig. 1

Wilsonoceras bighornense. A. K. Miller, The Cephalopods of the Big Horn formation of the Wind River mountains of Wyoming; Trans. Connecticut Acad. Arts and Sciences, 31, 258; pl. 16, fig. 1; pl. 17, figs. 2–4; pl. 18, fig. 1 (1932).

The specimen figured here is 165 cm. or 65 inches long when measured along its convex ventral outline, 65 cm. of this length belonging to the living chamber. At the base of the living chamber the maximum diameter of the last volution of the phragmacone across the umbilical area is 31 cm.; that of the immediately preceding volution having been 14.5 cm. Of this preceding volution a length of only 18.5 cm. remains. In this length of 18.5 cm. the dorsoventral diameter of the cast of the interior of the conch enlarges from 28 mm. at its smaller end to 46 mm. at its top, increasing to 69 mm. in the next half volution, and to 94 mm. at the base of the living chamber. From these measurements it is evident that the angle of enlargement of the phragmacone, as far as preserved, diminishes in successive half volutions from 5.5 to 4, finally to 3 degrees. Along the living chamber it is even less, the dorsoventral diameter of the latter equalling only 98 millimeters at its top. The lateral diameter of this specimen is not preserved but is estimated to have been about 135 millimeters at the top of the phragmacone. The cross section of the conch apparently is less depressed at earlier stages of growth. The volutions apparently are in light contact with each other along the phragmacone, the dorsal side being slightly impressed locally along the upper part of the latter. The living chamber becomes free between 50 and 70 millimeters above its base, and remains curved though strongly divergent from the preceding volution.

At a dorsoventral diameter of 35 mm. there are 2 camerae in a corresponding length ventrally, increasing to 2.5 camerae at a diameter of 60 mm.; to 3.5 camerae at 65 mm.; to 4 camerae at 70 mm.; to 5 camerae at 80 mm.; and to 10 camerae at the top of the phragmacone where its diameter is 94 mm. This crowding of the camerae at the top of phragmacone indicates that the conch had attained gerontic conditions. The sutures of the septa apparently rise slightly ventrolaterally and then curve conspicuously and broadly downward ventrally. The concavity of the septa equals fully 20 mm. at the top of the phragmacone. Here the thickness of the shell is 4 mm. dorsally. U. S. National Museum, no. 90947. Plate XVI, fig. 1.

In another specimen, a well preserved fragment of a phragma-

cone, the dorsoventral diameter of the conch is 76 mm. at a lateral diameter of 106 mm. The passage of the siphuncle through the septum is 12 mm. in diameter and its center is 21 mm. from the dorsal wall of the conch. The ventral side of its cross section is distinctly flattened so that its maximum lateral diameter is located about 24 mm. from the ventral outline of the conch. The sutures of the septa curve broadly downward ventrally for a depth of 20 mm.

In several specimens the ratio of the dorsoventral diameter of the conch to its lateral one varies between 67 and 71 per cent.

Only one specimen exposes a segment of the siphuncle. Where the height of the camera is 14 mm. its maximum lateral diameter is 10 or 11 mm., its general form being elliptically elongated.

Several specimens indicate the presence of relatively narrow transverse ribs, curving strongly downward laterally. In one specimen with a dorsoventral diameter of 90 mm. this downward curvature equals fully 60 mm., ten ribs occurring in a length of 45 mm. ventrolaterally.

Occurrence: On the south side of Middle Fork of Popo Agie River, 8 miles west of Lander, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90947.

56. **Wilsonoceras** cf. **bighornense** Miller

Plate XVII, Figs. 1, 2, 3, 4

The large specimen figured consists of the upper two thirds of the last volution of a phragmacone, the length of the part preserved being estimated at about 50 mm. ventrally in its original condition. The maximum diameter of this last volution of the phragmacone across its umbilical area is 270 mm. At its larger end the dorsoventral diameter is 78 mm. and its lateral one is 107 mm. The passage of the siphuncle through the uppermost septum preserved is 12 mm. in diameter and its center is 27 mm. from the dorsal wall of the conch. The dorsal side of the cross section is almost flat medially, but is very faintly impressed locally. At its lower end, where the dorsoventral diameter is about 70 mm.,

there are 4 camerae in a corresponding length ventrally. At its upper end, for a length of 50 mm., the camerae are much shorter, the conch evidently having reached its gerontic stage of growth. The sutures of the earlier septa curve distinctly downward medially. Plate XVII, figs. 1, 2, 4.

In a second fragment, 115 mm. long and estimated to have had a dorsoventral diameter of 65 mm., there were about 3 camerae in a corresponding length ventrally. The passage of the siphuncle through the septa is about 6 mm. in diameter, and its center is 20 mm. from the ventral wall of the conch. The septal necks are short and the connecting rings are almost globular in form, 15 mm. long and 14 mm. wide, with their upper and lower ends somewhat truncated. Plate XVII, fig. 3.

Occurrence: Teton creek canyon, in the western foot-hills of the Teton range, within the limits of Idaho, northeast of Driggs. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90948.

57. **Wilsonoceras brevicameratum** new species

Plate XVIII, Fig. 1

The holotype, and only specimen known, is 320 mm. long and has a radius of curvature of 140 to 160 mm. along its convex ventral outline. A little above midlength its lateral diameter is 97 mm. and its dorsoventral one is 62 mm. Along all but the lower 55 mm. of its length there are 7 camerae in a length of 62 mm. ventrally, the cameration not being preserved distinctly along the lower 55 mm. The sutures of the septa rise from the dorsal side toward its ventrolateral part and then curve downward ventrally, forming broad V-shaped lobes, subangular along their median part, with a depth of 22 mm. beneath the ventrolateral saddles. Dorsally these sutures form similar V-shaped lobes 25 mm. deep, also subangular medially. The median part of the dorsal side of the conch is faintly impressed.

Occurrence: South side of Middle Fork of Popo Agie River, miles west of Lander, Wyoming. From the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90949.

Remarks: This specimen evidently belongs to the upper part of the phragmacone, but the camerae are of uniform length in a distance of at least 250 mm. ventrally. This suggests that the specimen belonged to a short camerated form and was not merely a gerontic part of a long camerated species, such as *Wilsonoceras bighornense*. Moreover, the V-shaped lobes of the sutures ventrally also appears characteristic. The similarly V-shaped dorsal lobes, however, are known also in *Wilsonoceras bighornense*, the sutures of the septa of the latter usually being directly transverse dorsally at earlier stages of growth, but curving increasingly downward at later stages, not infrequently becoming V-shaped on approaching gerontic conditions. The dorsoventral diameter of this specimen is relatively short, compared with its lateral one.

The gerontic individual figured by Miller on plate 18 of his publication on the Cephalopods of the Big Horn formation of the Wind River Mountains of Wyoming shows numerous short camerae at gerontic stages of growth; however, there appears to be no strong dorsoventral depression of this part of the conch.

CHARACTOCERAS Foerste

Genotype: *Trochoceras baeri* Meek and Worthen. Proc. Acad. Nat. Sci. Philadelphia, 17, 263 (1865); Foerste, *Charactoceras baeri*, Jour. Sci. Labs. Denison Univ., 20, 235, pl. 31, fig. 1; pls. 32, 33, 34 (1924).

Conch nautiloid, depressed dorsoventrally, with a distinct dorsal impressed zone. The transverse striae on the surface of the shell indicate that the hyponomic sinus was broad and relatively deep but not abrupt. The sutures of the septa curve slightly downward laterally and rise higher ventrally than dorsally. The siphuncle is located on the ventral side of the conch but not near contact with the latter. The segments of the siphuncle enlarge but moderately within the camerae, being distinctly elongated lengthwise. There is no trace of transverse ribs.

The species described here as *Charactoceras* (?) *canyonense* is referred to this genus only because no transverse ribs can be detected on the fragments preserved. However, it should be remembered that these ribs usually are preserved best on the

dorsolateral sides of the phragmacone, and only when the latter are fairly well preserved.

58. **Charactoceras (?) canyonense** new species

Plate XXII, Figs. 1, 2, 3; 4, 5

A single fragment of a living chamber with a single camera attached to its base is 80 mm. long ventrally, the radius of curvature of its ventral outline equalling 60 mm. At midlength its lateral diameter is 60 mm. and its dorsoventral one, when measured from the depth of the dorsal impressed zone, is 37 mm., the depth of this zone here being about 4 mm. The dorsoventral diameter of the chamber, measured from the depth of this zone, increases from 35 mm. to 40 mm. in a length of 25 mm. Its rate of enlargement laterally can not be determined. The cross section of this chamber at midlength has a radius of curvature of 40 mm. for a width of 45 mm. ventrally, shortening to about 15 mm. laterally. The dorsal impressed zone increases in width from 15 mm. at its base to about 21 mm. at a point 25 mm. farther up. Its depth increases from 3 mm. to 4.5 mm. in the same interval. The angle of involution is conspicuously elevated, its exterior side being bordered by a shallow depression nearly 10 mm. wide along the upper part of the chamber. The single camera at the base of the chamber is only 3 mm. long at its center, the septum here curving downward with a depth of 11 or 12 mm. The shortness of the camerae may be due to the conch having reached its gerontic stage of growth. No trace of the siphuncle is preserved. (Plate XXII, figs. 1, 2, 3.)

Occurrence: This living chamber was found 2.5 miles northwest of Canyon City, in the Harding quarry, by C. D. Walcott. It is from the granular limestone forming the basal part of the Fremont formation, between 4 and 8 feet above the Harding sandstone. U. S. National Museum, no. 90950.

Another specimen, from Eight Mile Mountain, north of the Parkdale road, between 4 and 8 miles north of Canyon City, Colorado, was collected by S. W. Loper. This specimen consists

of the basal part of the living chamber and of 5 camerae. The living chamber is preserved dorsally for a length of 20 mm. At the base of this chamber the lateral diameter is 50 mm. and the dorsoventral one is 29 mm. when measured from the depth of the dorsal impressed zone. Here the impressed zone is about 22 mm. wide and 6 mm. deep. The angle of involution is about as angular as in the preceding specimen and the dorsal impressed zone enlarges at about the same rate. Each of the lower two camerae has a height of 7.5 mm. ventrally, the following three camerae becoming successively shorter. U. S. National Museum, no. 90951. (Plate XXII, figs. 4, 5.)

These two specimens indicate the presence, in the lower part of the Fremont formation, of a coiled cephalopod closely related to typical *Charactoceras*. There is a possibility that its ventrolateral parts were faintly ribbed, but no trace of such ribbing can be recognized in the specimens at hand.

CHARACTOCERINA new genus

Genotype: *Eurystomites plicatus* Whiteaves. Geol. Surv. Canada, Pal. Foss., 3, pt. 3, 225, text figs. 15, 16; pl. 22, fig. 2 (1897); *Charactoceras* (?) *plicatum* Foerste, Jour. Sci. Labs. Denison Univ., 24, 171, pl. 14, figs. 1 A, B, C (1929).

Conchs closely similar to *Charactoceras* in form, but differing in the presence of transverse ribs on the dorsolateral sides of the conch, especially at earlier stages of growth; usually these ribs become obsolete ventrolaterally. The segments of the siphuncle enlarge but slightly within the camerae, even less than in typical *Charactoceras*. In addition to the genotype, from the lower or Dog Head member of the Red River formation in southern Manitoba, two species, *Charactoceras ? costatulum* and *Charactoceras ? washakiense*, were described by A. K. Miller from the basal sandstone of the Big Horn formation of the Big Horn formation in Wyoming. The two species described here, *Charactocerina kirki* and *Charactocerina multicamerata*, are from the same horizon at two localities in Wyoming.

59. **Charactocerina kirki** new species

Plate XX, Figs. 1, 2, 3, 4

The holotype is 285 mm. long, measured along its ventral outline as far as the base of the hyponomic sinus at its top; 140 mm. of this length belongs to the living chamber. The lower end of this specimen extends only 5 mm. beyond a complete volution measured from its top. The maximum diameter of the specimen, measured across its umbilical area, equals 128 mm. The dorsoventral diameter of the conch enlarges from 19 mm. at its base to 43 mm. at the base of the living chamber, and to 64 mm. at its top. The corresponding lateral diameters are 30 mm., 60 mm., and 86 mm. The dorsal side of the conch is distinctly impressed medially, the impressed zone varying in width from 8 or 9 mm. at its lower end to 17 or 18 mm. at the base of the living chamber, and to 20 or 21 mm. at a point 15 mm. beneath the dorsal outline of the aperture. The depth of this impressed zone increases from 1 mm. at its base to 4.5 mm. at the base of the living chamber, and then diminishes to 2 mm. at the point 15 mm. beneath the aperture. Since there are no indications of gerontic stages of growth, the living chamber, at later stages, may have become free from the preceding volution. In general, the cross section of the conch is broadly elliptical, with its maximum lateral diameter located a little dorsad of the center of the conch. There is also a slight flattening of the ventral side of the conch, resulting in rather faint ventrolateral angles, toward which the sutures of the septa rise.

At a lateral diameter of 42 mm. there are 6 camerae in a corresponding length ventrally. At a diameter of 60 mm. there also are 6 camerae. The sutures of the septa at the lower end of the specimen rise distinctly from the dorsal side in a ventrad direction, with a slight median lobe along the median part of the ventral side. Along the upper part of the phragmacone they curve slightly downward laterally, form low ventrolateral saddles, and the median ventral lobes become broader and deeper. At the base of the living chamber this lobe is 35 mm. wide and 5 mm. deep. At a lateral diameter of 48 mm. and a dorsoventral one of 35.5 mm., the depth of the dorsal impressed zone is 3 mm.; the con-

cavity of the septum is 7 mm.; the passage of the siphuncle through this septum is 3.8 mm. in diameter, and its center is 7.5 mm. from the ventral wall of the conch. The septal neck here is about 1 mm. long, but nothing is known of the form of the connecting rings.

The surface of the cast of the interior of the conch is distinctly ribbed laterally, the ribs being most distinct along the lower 85 mm. of the length of the conch when measured ventrally. Here the ribs are most distinct along the median part of the lateral sides, fading out rapidly in a ventrad direction, but continuing fairly distinct in a dorsad direction as far as the angles of involution. Along the median part of the ventral side of the conch there are faint traces of transverse lines. At a lateral diameter of 38 mm. these ribs and lines indicate the former presence of a hyponomic sinus with a depth of 25 mm. Along the upper part of the phragmacone these ribs are fairly distinct only between the faintly indicated dorsolateral angles and the line of involution dorsally. Along the living chamber they are almost obsolete, though faint transverse lines indicate a former hyponomic sinus almost 38 mm. deep where the lateral diameter of this chamber is 76 mm. Laterally the faint transverse lines number about 10 in a length of 13.5 mm. The ventral part of the aperture of this chamber is preserved only ventrolaterally.

Occurrence: Head of the north fork of Bear Trap Creek, on the southeast side of the Big Horn Mountains, in west central Johnson county, Wyoming. In the basal sandstone of the Big Horn formation, here 3 feet thick. Collected by Edwin Kirk. U. S. National Museum, no. 90952.

Remarks.—The lateral view of *Charactocerina kirki* closely resembles that of *Charactocerina costatula* (Miller), but the conch coils less rapidly lengthwise, enlarges more rapidly dorsoventrally, its diameter in that direction being conspicuously greater compared with the lateral one, and it attains a larger size. From *Charactocerina washakiensis* (Miller), figured in the same publication, it differs chiefly in its greater dorsoventral diameter and in the more rapid enlargement of the conch in that direction.

Possibly the specimens described by Miller were depressed dorsoventrally after the death of the animal. The absence of well marked plications on the ventrolateral sides of the holotype of *Charactocerina washakiensis* probably is merely a gerontic feature.

60. **Charactocerina multicamerata** sp.

Plate XXI, Figs. 1, 2

The holotype, as far as preserved, includes about two thirds of the last volution of the conch. Its length along its ventral outline equals 142 mm. Its maximum diameter, measured across its umbilical area, is 85 mm. The radius of curvature of the ventral outline of the living chamber is 60 mm.; that of the phragmacone evidently is shorter but can not be determined with accuracy owing to distortion of this part of the conch. The lateral diameter enlarges from 51 mm. at a point 30 mm. beneath the living chamber to 55 mm. at the base of this chamber, and to 61 mm. at a point 75 mm. above this base. The corresponding dorsoventral diameters are approximately 26 mm., 26 mm., and 31 mm., as far as can be determined in the present distorted condition of the specimen. The rate of enlargement of the earlier parts of the conch must have been considerably greater. The cross section of the conch is strongly flattened ventrally, the ventral sides converging in a dorsad direction, resulting in fairly distinct ventrolateral angles. The dorsal side of the conch is not exposed. At the top of the phragmacone, where its lateral diameter is 55 mm., there are 12 camerae of nearly equal height in a corresponding length. The sutures of the septa are almost directly transverse, with a very slight downward curvature along the median part of its ventral side along the upper part of the phragmacone. The siphuncle is not exposed. Along the ventrolateral angles of the lower part of the living chamber there are 4 distinct ribs in a length of 30 mm., followed by more obscure ones farther up. These ribs are most conspicuous ventrolaterally, becoming rapidly weaker both ventrally and dorsally. Similar ribs occur along the upper part of the phragmacone, about 6 in a length of 32 mm. best preserved between 33 and 65 mm. beneath

the living chamber. There are also faint traces of transverse raised lines, about 11 in a length of 10 mm. ventrally along the living chamber. These and the ventrolateral ribs curve downward ventrally so as to indicate the former presence of hyponomic sinuses 30 mm. in depth.

Occurrence: On the south side of the Middle Fork of Popo Agie River, 8 miles west of Lander, in Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90955.

FREMONTOCERAS new genus

Genotype *Fremontoceras loperi* Foerste.

Conch coiled, possibly gyroceraconic; at least there is no indication of contact between successive volutions; enlarging rapidly, only a part of the phragmacone being known. Cross section subquadrangular, with a slight flattening of the lateral sides and a more distinct flattening of the ventral one, resulting in a tendency toward angulation ventrolaterally. The sutures of the septa rise slightly toward these ventrolateral angles, and then curve distinctly downward ventrally, resulting in ventrolateral saddles and ventral lobes, the latter being only of moderate depth. The siphuncle is located ventrad of the center of the conch. Nothing is known of the form or interior structure of its segments.

61. **Fremontoceras loperi** new species

Plate XIX, Figs. 1, 2, 3, 4

The holotype is 250 mm. long, measured along its ventral outline. The radius of curvature of this outline increases from 90 mm. along its lower half to 130 mm. toward its top. The maximum diameter of the volution of which this fragment is the upper half, across the umbilical area, is estimated at 185 mm. This fragment enlarges dorsoventrally from a diameter of 49 mm. near its base to 79 mm. at a point 200 mm. farther up. The corresponding lateral diameters are 53 and 80 mm. The cross section of the conch is nearly circular along four fifths of its circumference but is distinctly flattened ventrally and subangular ventrolater-

ally, so as to result in a subquadrangular appearance. At diameters of 53 and 65 mm. there are 3 camerae in a corresponding length; at 80 mm. there are 3 camerae in a length of 75 mm. ventrally. The sutures of the septa curve only faintly downward laterally, rising moderately from the dorsal side toward the ventrolateral saddles and then curving distinctly downward into broad ventral lobes 7 or 8 mm. in depth. At a dorsoventral diameter of 57 mm. the passage of the siphuncle through the septum is 8 mm. in diameter, and its center is 13 mm. from the ventral wall of the conch. The septal necks are about 1.5 mm. long and their lower margins appear to curve outward, but the connecting rings are not exposed.

Occurrence: Eight Mile Mountain, north of the Parkdale road, between 4 and 8 miles north of Canyon City, Colorado. In the basal part of the Fremont formation. Collected by S. W. Loper. U. S. National Museum, no. 90953.

PLECTOCERAS Hyatt

Genotype: *Nautilus Jason* Billings. Canadian Nat. Geol., 4, 464 (1859); *Plectoceras Jason* Whiteaves, Geol. Surv. Canada, Pal. Foss., 3, pt. 4, 301, pl. 36, figs. 1, 2 (1906).

Conch gyroceraconic, its apical end conspicuously free from contact with the following volution. The umbilical opening is 5 to 7 mm. wide, quickly narrowing to 3 mm. in width on the ventral side of this apical end, and then more gradually to 1 mm. in a distance of 30 to 60 mm. Even the dorsal side of the living chamber usually is free, though apparently there may be weak contact locally for a short length. The sutures of the septa curve downward laterally and rise about the same height ventrally as dorsally. The diameter of the siphuncle equals about a seventh or an eighth of that of the conch, and its distance from the ventral wall of the latter is about the same or a little less than this diameter. The surface of the shell is distinctly annulated or ribbed, the ribs curving strongly downward in a ventrad direction laterally, indicating the former presence of a deep hyponomic sinus, rounded at the base. In addition there are striations

parallel to the ribs. The cross section of the conch is more broadly rounded ventrally than laterally, but there is no trace of ventrolateral angulation; slightly depressed dorsoventrally.

This genus is unknown at present from strata above the Chazyan.

METAPLECTOCERAS new genus

Genotype: *Inachus undatus* (*pars*) Conrâd MSS. in Emmons, Nat. Hist. New York, Geol., vol. 2, 394, text fig. 104 (1842); *Lituites undatus* (pars) Hall, Pal. New York, vol. 1, 52, pl. 13, fig. 1; pl. 13 bis, fig. 1 (1847); *Plectoceras undatum* Foerste, Jour. Sci. Labs. Denison Univ., 23, 46, pl. 15, figs. 1 A, B, 2; pl. 16, fig. 1; pl. 26, figs. 3, 4 (1928).

Conch similar to that of *Plectoceras* in the more or less distinct transverse ribbing and striation of the surface of the shell, but successive volutions in contact with each other. In the more typical species, as indicated by Foerste on plate 26 of the publication cited above, this contact takes place without any distinct dorsal impressed zone. The ventral side of the cross section of the conch tends to be more or less distinctly flattened, this flattening in some species relatively slight, but with a tendency toward angularity along the ventrolateral parts of the cross section. The siphuncle, as in *Plectoceras,* is of moderate size and is at a distance practically equalling its diameter from the ventral wall of the conch.

The species included in this genus are those formerly listed as *Plectoceras undatum* Hall, *Pl. occidentale* Hall, *Pl. halli* Foord, and *Pl. lowi* Foerste, all from the Black River formation.

Whether the specimen described here as *Metaplectoceras landerense,* from the basal sandstone of the Big Horn formation, belongs to this genus can not be determined in the absence of any knowledge of its cross section or of the structure of its interior. It appears to be related more closely to the species described by Whiteaves as *Discoceras canadense,* from the lower or Dog Head member of the Red River formation of southern Manitoba, differing from the latter chiefly in its more distant plications.

62. **Metaplectoceras landerense** new species

Plate XXI, Fig. 3

The specimen here figured is about 105 mm. long when measured along its convex ventral outline. The radius of curvature of this ventral outline is about 35 mm. Its dorsoventral diameter can not be determined with accuracy at any point, but it is estimated to have increased from approximately 20 mm. at its lower end to 25 mm. at its top. Its lateral diameter is unknown, but the conch is assumed to have been compressed laterally. At the lower end of the specimen there are 3 conspicuous ribs in a length of 27 mm. measured ventrally. At its top the ribs are less conspicuous and 3 ribs occupy a length of only 20 mm. The ribs diminish in height over the intervening grooves from 1 mm. at the lower end of the specimen to about half this height at its top. These ribs rise slightly from the dorsal side of the conch toward its dorsolateral parts, and then curve increasingly downward ventrally, indicating the former presence of an hyponomic sinus 10 mm. deep. Parallel to these ribs there are faintly raised lines, about 5 in a length of 6 mm. laterally.

Occurrence: South side of the Middle Fork of Popo Agie River, 8 miles west of Lander, Fremont county, Wyoming. In the basal sandstone of the Big Horn formation. Collected by Edwin Kirk. U. S. National Museum, no. 90954.

DECKEROCERAS new genus

Genotype: *Deckeroceras adaense* Foerste.

Conchs strongly curved lengthwise, cross sections nearly circular, becoming distinctly depressed at the aperture. Hyponomic sinus broad and shallow. Siphuncle located on the convex ventral side of the conch, but at a distance of several millimeters from the ventral wall. Its segments are approximately cylindrical, except in the immediate vicinity of the septa, where they contract in an oblique manner when viewed along a dorsoventral vertical section.

Known at present only from the Fernvale and Maquoketa phases of the Richmond.

63. **Deckeroceras adaense** new species

Plate XXI, Fig. 4

The holotype consists of a strongly curved living chamber to which 3 camerae still are attached. Along its ventral outline it has a length of 103 mm., 68 mm. of this length belonging to the living chamber. Here its radius of convex curvature increases from 50 mm. along its lower half to 60 mm. farther up. The corresponding radius of curvature of its concave dorsal outline decreases from 50 mm. along its lower half to 15 mm. near its top. Its dorsoventral diameter increases from 45 mm. at the base of the living chamber to 49 mm. at a point 25 mm. farther up and then decreases to 44.5 mm. at the aperture. The corresponding lateral diameters are 46.5 mm., 51 mm., and 50 mm., the cross section being almost circular except at the aperture where it is distinctly depressed. Each of the two lower camerae is 11 mm. long ventrally, the third and overlying camera being only 5 mm. long, the conch evidently having reached its gerontic stage of growth. The concavity of the uppermost septum is 11 mm. The sutures of the septa curve only slightly downward laterally, both the dorsal and ventral margins reaching about the same level transversely. The siphuncle is 3 mm. in diameter and its center is 5 mm. from the ventral wall of the conch. Only the cast of the interior of the conch is known and this is smooth. Plate XXI, fig. 4.

In a second specimen of about the same size the dorsoventral diameter increases from 40 mm. at the base of the living chamber to 43.7 mm. at a point 30 mm. farther up ventrally, and then decreases to 39 mm. at the aperture. The corresponding lateral diameters are 45 mm., 49 mm., and 46 mm. Parts of 3 camerae remain attached ventrally.

Occurrence: From the Lawrence quarry, 7 miles southwest of Ada, Pontotoc county, Oklahoma. From the Fernvale formation immediately above the typical Viola formation. Collection of Charles E. Decker.

64. Deckeroceras sp.

Plate XXI, Fig. 5

A specimen similar to *Deckeroceras adaense* was found south of the bridge over Rogers Creek, east of Fort Atkinson, in Winneshiek county, Iowa, in the Vogdesia zone of the Elgin member of the Maquoketa shale. Collected by Harry S. Ladd.

Its dorsoventral diameter at the base of the living chamber is 45 mm. Only 2 camerae are attached to its base, the lower one 12 mm. in length along the siphuncle, and the upper one only 4 mm. long. The siphuncle is nearly 5 mm. in diameter and its center is 10 mm. from the ventral wall of the conch. The segments of the siphuncle contract obliquely at their passage through the septa to a diameter of 4 mm. when measured parallel to the septa. Plate XXI, Fig. 5.

Another specimen, apparently congeneric, but with 4 camerae in a length of 14 mm. when measured laterally, was found by A. O. Thomas in the upper beds of the Elgin member of the Maquoketa shale in Springfield township of Winneshiek county, Iowa, along the road separating sections 24 and 23, three miles southeast of Nordness.

LITERATURE REFERENCES

(*1*) Troedsson, Gustaf T. On the Middle and Upper Ordovician faunas of Northern Greenland. Pt. 1, Cephalopods. Jubilaeumsekspeditionen nord om Grønland, 1920–23, no. 1 (1926).

(*2*) Foerste, Aug. F. Contributions to the Geology of Foxe land, Baffin Island; by Laurence M. Gould, Aug. F. Foerste, and Russell C. Hussey. Contrib. from Mus. Pal., Univ. Michigan, 3, no. 3, 25–69 (1928).

(*3*) Foerste, Aug. F. and Savage, T. E. Ordovician and Silurian cephalopods of the Hudson Bay area. Jour. Sci. Labs., Denison Univ., 22 (1917).

(*4*) Foerste, Aug. F. The cephalopods of the Red River Formation of Southern Manitoba. Jour. Sci. Labs. Denison Univ., 24 (1929).

(*5*) Miller, A. K. The cephalopods of the Bighorn Formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 193–297 (1932).

(*6*) Walcott, Charles D. Preliminary Notes on the Discovery of a Vertebrate Fauna in Silurian (Ordovician) Strata. Bull. Geol. Soc. America, 3, 153–172 (1892).

(*7*) Decker, Charles E. Viola limestone, primarily of Arbuckle and Wichita Mountain Ranges, Oklahoma. Bull. Amer. Assn. Petroleum Geologists, 17, 1419, 1422, 1425–28, 1434 (1933).

(8) Kay, G. Marshall. Ordovician Stewartville-Dubuque Problems. Geol. Soc. Amer. Bull. and personal communications (1934).

(9) Clarke, John M. Geology of Minnesota, vol. 3, pt. 2, 793, 798, pl. 56, figs. 1, 2, pl. 58, figs. 16-18 (1897).

(10) Kay, G. Marshall. Personal communications.

(11) Sardeson, F. W. Name of Dubuque formation proposed in article on Galena Series. Bull. Geol. Soc. America, 18, 193-4 (1907).

(12) Winchell, N. H. and Ulrich, E. O. Maclurea bed discussed in preface on The Lower Silurian deposits of the Upper Mississippi Province. Geology of Minnesota, vol. 3, pt. 2, page ci (1897).

(13) Foerste, Aug. F. and Savage, T. E. Ordovician and Silurian Cephalopods of the Hudson Bay Area. Denison Univ. Bull., Jour. Sci. Labs., 22, 43, pl. 4, figs. 3A, B (1927).

(14) Decker, Charles E. Viola Limestone, primarily of the Arbuckle and Wichita Mountain Regions, Oklahoma. Bull. Amer. Assn. Petroleum Geologists, 17, 1414, 1418, and numerous other citations (1933).

(15) Kirk, Edwin. The Harding Sandstone of Colorado. Amer. Jour. Sci., 20, 465 (1930).

(16) Walcott, Charles D. Preliminary Notes on the Discovery of a Vertebrate Fauna in Silurian (Ordovician) Strata. Bull. Geol. Soc. America, 3, 156, 157, 159, 160 (1892).

(17) Kirk, Edwin. The Harding Sandstone in Colorado. Amer. Jour. Science, 20, 463 (1930).

(18) Miller, A. K. Cephalopods of the Big Horn Formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 230, pl. 5, figs. 1, 2 (1932).

(19) Foerste, Aug. F. Cephalopods of the Red River Formation of Southern Manitoba. Denison Univ. Bulletin, Jour. of the Sci. Labs., 24, 161, pl. 37, figs. 4A, B (1929).

(20) Foerste, Aug. F. Jour. Sci. Labs. Denison Univ., 24, 217, pl. 16, fig. 6 (1929).

(21) Schuchert, Charles. On the Lower Silurian (Trenton) Fauna of Baffin Land, U. S. Nat. Mus., Proc., 22, 172, pl. 14, figs. 1-3 (1900).

(22) Foerste, Aug. F., and Savage, T. E. Ordovician and Silurian Cephalopods of the Hudson Bay Area. Jour. Sci. Labs. Denison Univ., 22, 55, pl. 16, figs. 2A, B (1927).

(23) Whiteaves, J. F. Geol. Surv. Canada, Pal. Foss., vol. 3, pt. 4, 282 (1906); Ottawa Naturalist, 20, 133, text figs. A, B (1906).

(24) Whiteaves, J. F. Geol. Surv. Canada, Pal. Foss., vol. 3, pt. 4, p. 282 (1906); Ottawa Nat., 20, 133, text figs. A, B (1906).

(25) Hyatt, Alphaeus. Genera of Fossil Cephalopods, Proc. Boston Soc. Nat. Hist., 22, 287 (1884).

(26) Troedsson, Gustaf T. On the middle and upper Ordovician faunas of northern Greenland, pt. 1, p. 93, pl. 1, figs. 3, 4; pl. 55, figs. 4-9 (1926).

(27) Foerste, Aug. F. In W. H. Twenhofel, Geology of Anticosti Island, memoir 154, Geological Survey of Canada, p. 316, pl. 55, figs. 1-3 (1928).

(28) Foerste, Aug. F. The Cephalopods of the Red River formation of southern Manitoba. Jour. Sci. Labs. Denison Univ., 24, 226, pl. 35, fig. 2 (1929).

(29) FOERSTE, AUG. F. Black River and other cephalopods from Minnesota, Wisconsin, Michigan, and Ontario. Jour. Sci. Labs. Denison Univ., 27, pl. 34, figs. 1, 2 (1932); 28, 143 (1933).

(30) FOERSTE, AUG. F. AND SAVAGE, T. E. Ordovician and Silurian cephalopods of the Hudson Bay area. Jour. Sci. Labs. Denison Univ., 22, 86, pl. 16, figs. 1 A, B, C (1927).

(31) FOERSTE, AUG. F. In W. H. Twenhofel, Geology of Anticosti. Memoir 154, pp. 318–319, pl. 44, figs. 3, 4; pl. 55, figs. 4, 5 (1928).

(32) FOERSTE, AUG. F. Three Studies of Cephalopods. Jour. Sci. Labs. Denison Univ., 24, 314, pl. 47, fig. 5 (1929).

(33) FOERSTE, AUG. F. A restudy of some of the Ordovician and Silurian cephalopods described by Hall. Jour. Sci. Labs. Denison Univ., 23, 209, pl. 44, figs. 2 A, B (1928).

(34) FOERSTE, AUG. F. Arctic and related cephalopods. Jour. Sci. Labs. Denison Univ., 23, 103, pl. 9, figs. 2 A, B, C (1928).

(35) MILLER, A. K. The Cephalopods of the Big Horn formation of the Wind River Mountains of Wyoming. Trans. Connecticut Acad. Arts, Sciences, 31, 293, pl. XXX, figs. 2, 3 (1932).

(36) FOERSTE, AUG. F. Denison Univ. Bull., Jour. Sci. Labs., 24, 169, pl. XIII, figs. 2 A, B, C (1929).

(37) FOERSTE, AUG. F. Arctic and Related Cephalopods. Jour. Sci. Labs. Denison Univ., 23, 103, pl. 9, figs. 2 A, B, C (1928).

(38) MILLER, A. K. Trans. Connecticut Acad. Arts and Sciences, 31, 296, pl. XXXI, figs. 2, 3 (1932).

(39) FOERSTE, AUG. F. Port Byron and other Silurian cephalopods. Jour. Sci. Labs. Denison University, 25, 123, pls. 5, 11, 18, 21 (1930).

(40) MILLER, A. K. The cephalopods of the Bighorn formation of the Wind River mountains of Wyoming. Trans. Connecticut Acad. Arts and Sciences, 31, 294, pl. 30, fig. 1; pl. 31, fig. 1 (1932).

(41) FOERSTE, AUG. F. The cephalopods of the Putnam Highland. Contrib. Mus. Pal. Univ. Michigan, 3, 61, pl. 7, figs. 1, 2, 3 (1928).

PLATE I

All figures reduced to 0.79 in diameter

Figs. 1, 2. *Endoceras* (?) *paradoxicum* Foerste. Apparently a spiculum. 1, ventral side; 2, lateral side, with ventral outline on left. Popo Agie River, 8 miles west of Lander, Wyoming. From Lander sandstone, Big Horn formation. U. S. National Museum, no. 90898.

Fig. 3. *Probillingsites milleri* Foerste. Lateral view with dorsal outline on left. Elkador, Iowa. From the *Catazyga uphami* zone in the upper part of the Prosser formation. U. S. National Museum, no. 90900.

Figs. 4, 5. *Billingsites landerensis* Foerste. 4, dorsal view; 5, lateral view with ventral outline on left. Popo Agie River, 8 miles west of Lander, Wyoming. From Lander sandstone, Big Horn formation. U. S. National Museum, no. 90901.

Fig. 6. *Billingsites multicameratus* A. K. Miller. Dorsal view. Medicine Mountain, in northern Wyoming. From basal part of Big Horn formation. Collection of T. E. Savage.

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PLATE II

All figures reduced to 0.86 in diameter

Figs. 1, 2. *Neumatoceras nutans* Foerste. Left side, disjointed near top of phragmacone, showing siphuncle; 2, right side of same. Medicine Mountain, in northern Wyoming. From basal part of Big Horn formation. Collection of T. E. Savage.

Figs. 3, 4. *Neumatoceras gibberosum* Foerste. 3, lateral side with ventral outline on left; 4, another specimen, with ventral outline on right. Medicine Mountain, in northern Wyoming. From basal part of Big Horn formation. Collection of T. E. Savage.

Fig. 5. *Lambeoceras* cf. *cultratum* A. K. Miller. Ventral view. From Jo Daviess county, in northwestern Illinois. From the Stewartville formation. Univ. of Iowa, no. 700.

Figs. 6, 7. *Geisonocerin landerensis* Foerste. 6, Lateral view, conch faintly curved lengthwise with convex side on right; holotype; 7, another specimen, at gerontic stage of growth. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, nos. 90902 A, C, in order here figured. See also plate XI, fig. 4.

PLATE III

Fig. 1. *Richardsonoceras wyomingense* Foerste. Ventral outline on left. Popo Agie River, 10 miles west of Lander, Wyoming. From Lander sandstone of Big Horn formation. U. S. National Museum, no. 90917.

Fig. 2. *Endoceras landerense* Foerste. Lateral view, with siphuncle at base on right side. Popo Agie River, 8 miles west of Lander, Wyoming. From Lander sandstone of Big Horn formation. U. S. National Museum, no. 90897.

Figs. 3, 4. *Neumatoceras canyonense* Foerste. 3, Lateral view with dorsal outline on left; 4, dorsal view. Eight Mile Mountain, north of Parkdale road, north of Canyon City, Colorado. Basal part of Fremont formation. U. S. National Museum, no. 90911.

Fig. 5. *Neumatoceras* cf. *canyonense* Foerste. Lateral view with ventral outline on right. Popo Agie River, 8 miles west of Lander, Wyoming. From Lander sandstone of Big Horn formation. U. S. National Museum, no. 90912.

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PLATE IV

Fig. 1. *Westonoceras deckeri* Foerste. Lateral view with ventral outline on right. West of Bromide, Oklahoma. Near the top of the Viola formation. Collection of Charles E. Decker.

Fig. 2. *Winnipegoceras laticurvatum* Whiteaves. Lateral view with ventral outline on right. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90916.

Fig. 3. *Beloitoceras landerense* Foerste. Lateral view with ventral outline on left. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90909.

Fig. 4. *Neumatoceras* (?) *milleri* Foerste. Lateral view, with ventral outline on left. Popo Agie River. 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90913.

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BIG HORN AND RELATED CEPHALOPODS

PLATE V

All figures reduced to 0.80 in diameter

Figs. 1, 2, 3. *Neumatoceras* sp. 1, dorsal view; 2, lateral view with dorsal view on right; 3, ventral view. Eight Mile Mountain, north of Parkdale road, north of Canyon City, Colorado. U. S. National Museum, no. 90915.

Fig. 4. *Neumatoceras* sp. Lateral view with ventral outline on left. Head of North Fork of Bear Trap Creek, in west central Johnson County, Wyoming. In basal sandstone of Big Horn formation. U. S. National Museum, no. 90914.

Fig. 5. *Kionoceras paucicostatum* A. K. Miller. Lateral view of phragmacone. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90903.

Figs. 6, 7. *Landeroceras prolatum* A. K. Miller. 6, Ventral view; 7, ventrolateral view showing decurrent sutures in case of the upper septa. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90938-A, B.

PLATE V

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BIG HORN AND RELATED CEPHALOPODS

PLATE VI

All figures reduced to 0.80 in diameter

Fig. 1. *Lambeoceras landerense* Foerste. Holotype. Ventral view. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90926.

Fig. 2. *Lambeoceras* cf. *confertum* Foerste. With glimpses of segments of the siphuncle. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90925.

Fig. 3. *Lambeoceras acutilaterale* Foerste. Ventral view showing lateral extension of the shell beyond the camerated part. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90927.

Fig. 4. *Spyroceras* (?) *distoannulatum* Foerste. Lateral view. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90905.

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PLATE VII

All figures reduced to 0.80 in diameter

Figs. 1, 2. *Lambeoceras confertum* Foerste. Both fragments originally may have belonged to the same conch. Ventral views, the upper specimen showing one of the segments of the siphuncle. West of Scales Mound, Jo Daviess county, in northwestern Illinois. In the Stewartville formation. U. S. National Museum no. 90924.

Figs. 3, 4. *Richardsonoceras* (?) *subcuneatum* Foerste. 3, lateral view with dorsal outline on right; 4, ventral side, with siphuncle on the lower side of one of the upper camerae, exposed by a break. Eight Mile Mountain, north of Parkdale Road, north of Canyon City, Colorado. From the basal part of the Fremont formation. U. S. National Museum, no. 90918.

Fig. 5. *Neumatoceras breviposticum* A. K. Miller. With ventral outline on left, showing curvature of transverse ribs. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90910.

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PLATE VIII

Fig. 1. *Kochoceras grande* Foerste. Ventral view, reduced to 0.64 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90928.

Figs. 2, 3. *Nanno walcotti* Foerste. 2, Ventral view, showing siphuncle; 3, lateral view, with ventral outline on right. Both views reduced to 0.80 in diameter. Harding quarry, 2.5 miles northwest of Canyon City, Colorado. In the basal part of the Fremont formation. U. S. National Museum, no. 90899.

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PLATE IX

Fig. 1. *Diestoceras magister* Foerste. Lateral view, reduced to 0.75 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone in the Big Horn formation. Holotype. U. S. National Museum, no. 90929. See also plate X, fig. 1.

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PLATE X

Fig. 1. *Diestoceras magister* Foerste. View of aperture of living chamber, reduced to 0.84 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90930-A. See also plate IX, fig. 1.

Fig. 2. *Beloitoceras fremontense* Foerste. Lateral view with ventral outline on left, reduced to 0.95 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90907.

Fig. 3. *Beloitoceras popoagiense* Foerste. Lateral view with ventral outline on left, reduced to 0.95 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90908.

Fig. 4. *Oncoceras parvum* Foerste. Lateral view with ventral outline on left, reduced to 0.95 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90919.

Fig. 5. *Whitfieldoceras minimum* Foerste. Lateral view, reduced to 0.95 in diameter. Elkador, Iowa. From the *Catazyga uphami* zone in the upper part of the Prosser formation. U. S. National Museum, no. 90920.

Fig. 6. *Centrocyrtoceras rotundum* Foerste. Lateral view, with ventral outline on right, reduced to 0.95 in diameter. Elkador, Iowa. From the upper part of the Prosser formation. U. S. National Museum, no. 90906.

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BIG HORN AND RELATED CEPHALOPODS

PLATE XI

Figures 1–5 reduced to 0.86 in diameter; figure 6 enlarged to 1.72 in diameter

Fig. 1. *Diestoceras* cf. *landerense* A. K. Miller. Lateral view. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90931.

Fig. 2. *Diestoceras kirki* Foerste. Lateral view with more convex outline on left. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90933.

Fig. 3. *Diestoceras fremontense* Foerste. Lateral view with more convex outline on left. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90932.

Fig. 4. *Geisonocerina landerensis* Foerste. Ventral view of phragma cone. Popo Agie River, 8 miles west of Lander. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90902-B. See also plate II, figs. 6, 7.

Fig. 5. *Paractinoceras canadense* (Whiteaves). Dorsal view. Medicine Mountain, in northern Wyoming. From the basal part of the Big Horn formation. Collection of T. E. Savage.

Fig. 6. *Spyroceras* cf. *anellus* (Conrad). Lateral view. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. Figure enlarged to 1.72 in diameter. U. S. National Museum, no. 90904.

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PLATE XII

All figures reduced to 0.86 in diameter

Figs. 1, 2. *Fayettoceras canyonense* Foerste. 1, Lateral view with ventral outline on right; 2, dorsal view. Harding quarry, northwest of Canyon City, Colorado. From the basal part of the Fremont formation. U. S. National Museum, no. 90922. See also plate XXII, figs. 6, 7.

Figs. 3, 4. *Diestoceras occidentale* Foerste. 3, Lateral view with more convex outline on left; 4, ventral view, showing hyponomic sinus. Harding quarry, northwest of Canyon City, Colorado. From the basal part of the Fremont formation. Holotype. U. S. National Museum, no. 90935. See also plate XXII, fig. 8. Holotype.

Figs. 5, 6. *Diestoceras occidentale* Foerste. 5, Lateral view with more convex outline on left; 6, more convex side. Harding quarry, northwest of Canyon City, Colorado. U. S. National Museum, no. 90936.

Figs. 7, 8, 9. *Diestoceras walcotti* Foerste. 7, dorsal view; 8, ventral view showing siphuncle; 9, lateral view with ventral outline on left. Harding quarry, northwest of Canyon City, Colorado. From the basal part of the Fremont formation. U. S. National Museum, no. 90934.

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BIG HORN AND RELATED CEPHALOPODS

PLATE XIII

Fig. 1. *Cyrtogomphoceras perexpansum* Foerste. Dorsal view, reduced to 0.74 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone in the Big Horn formation. U. S. National Museum, no. 90939.

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BIG HORN AND RELATED CEPHALOPODS

PLATE XIV

All figures reduced to 0.75 in diameter

Fig. 1. *Cyrtogomphoceras rotundum* A. K. Miller. Lateral view with siphuncular side on right, and angulate along the left margin. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone in the Big Horn formation. For typical outline as shown by holotype see figure published by Miller. U. S. National Museum, no. 90943.

Fig. 2. *Cyrtogomphoceras vicinum* Foerste. Lateral view with siphuncular side on right. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90944.

Figs. 3, 4. *Cyrtogomphoceras popoagiense* Foerste. Both are lateral views with the siphuncular side on the right. Fig. 3 represents the holotype. Fig. 4 is slightly depressed dorsoventrally toward the top. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone in the Big Horn formation. U. S. National Museum, nos. 90941, 90942 in the order here figured.

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BIG HORN AND RELATED CEPHALOPODS

PLATE XV

All figures reduced to 0.80 in diameter

Figs. 1, 2, 3. *Cyrtogomphoceras contractum* Foerste. 1, lateral view with siphuncular side on left, single segment of siphuncle removed to show the outline of the septum at its base more clearly; 2, dorsal view; 3, ventral view showing fragment of a single segment of the siphuncle at its base. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90945.

Fig. 4. *Cyrtogomphoceras minor* Foerste. Lateral view of the living chamber with the siphuncular side on the right. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big River formation. U. S. National Museum, no. 90946.

Fig. 5. *Cyrtogomphoceras landerense* Foerste. Lateral view with the siphuncular side on the right. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90940.

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BIG HORN AND RELATED CEPHALOPODS

PLATE XVI

Fig. 1. *Wilsonoceras bighornense* A. K. Miller. Lateral view, reduced to 0.37 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90947.

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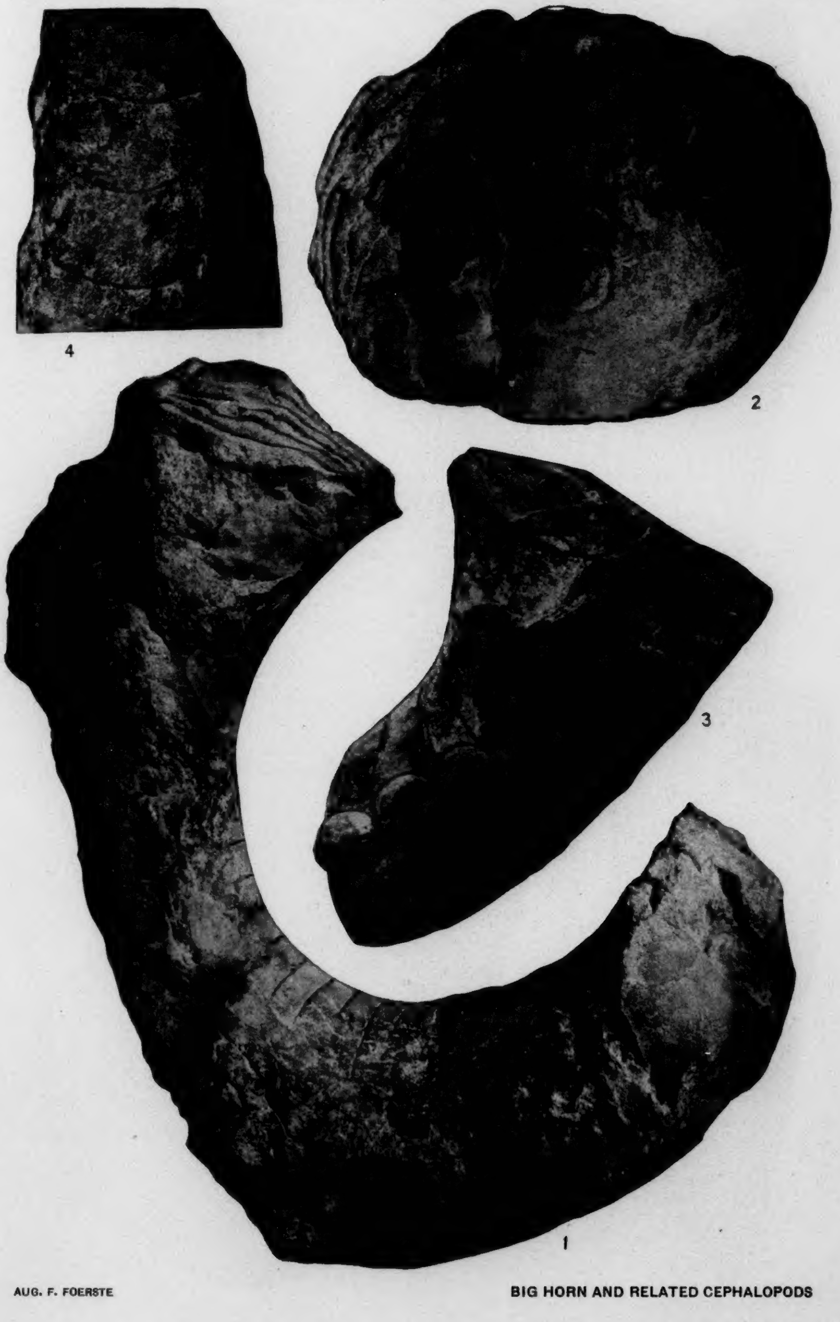
PLATE XVII

Figs. 1, 2, 3, 4. *Wilsonoceras* cf. *bighornense* A. K. Miller. 1, Lateral view of a phragmacone preserving the dorsal or concave outline, with closely crowded camerae at top, reduced to 0.66 in diameter; 2, view of septum exposed at top of same, with the concave side of the volution at its base, showing location of siphuncle on this side of the center of the conch; 3, dorsoventral section of a fragment originally probably attached to the basal part of that portion of the specimen illustrated by fig. 1, showing three segments of siphuncle in the lower camerae and passage of siphuncle through septum at its top, a considerable thickness of the convex outline of the conch being missing; 4, a short length of the ventral or convex side of the preceding volution of the conch, fitting near midlength of the concave side of fig. 1, showing the downward curvature of the sutures of the septa ventrally. Teton Creek canyon, west of the Teton Range, northeast of Driggs, within the limits of Idaho. In the basal sandstone of the Big Horn formation. Fig. 1 is reduced to 0.66 of diameter, and figs. 2, 3, and 4 are reduced to 0.80. U. S. National Museum, no. 90948.



AUG. F. FOERSTE BIG HORN AND RELATED CEPHALOPODS

PLATE XVIII

Fig. 1. *Wilsonoceras brevicameratum* Foerste. Convex or ventral side, reduced to 0.80 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90949.

Figs. 2, 3. *Tripterocerina kirki* Foerste. 1, dorsal view; 2, ventral view showing traces of cameration at its base; both views reduced to 0.86 in diameter. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90923.

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BIG HORN AND RELATED CEPHALOPODS

PLATE XIX

All figures reduced to 0.80 in diameter

Figs. 1, 2, 3, 4. *Fremontoceras loperi* Foerste. 1, lateral view of phragmacone; 2, lateral view of basal part of specimen oriented to show the small downward curvature of the sutures of the septa laterally and their much larger curvature ventrally; 3, ventral view of same fragment as fig. 2; 4, base of camera immediately overlying figs. 2 and 3, with subquadrangular ventral outline at top, showing location of siphuncle ventrad of the center of the conch. Eight Mile Mountain, north of Parkdale road, north of Canyon City, Colorado. From the basal part of the Fremont formation. U. S. National Museum, no. 90953.

Fig. 5. *Digenuoceras* cf. *latum* Foerste. Lateral view with ventral outline on right. Medicine Mountain, in northern Wyoming. From the basal part of the Big Horn formation. Collection of T. E. Savage.

PLATE XIX

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BIG HORN AND RELATED CEPHALOPODS

PLATE XX

All figures reduced to 0.80 in diameter

Figs. 1, 2, 3, 4. *Charactocerina kirki* Foerste. 1, lateral view; 2, dorsal view of that part of the specimen included between the two fractures indicated in fig. 1, showing narrow but distinct dorsal impressed zone, also with trace of siphuncle at its base; 3, basal part of specimen, lateral view, sectioned at top to show septation and passage of siphuncle through upper septa, but form of segments of siphuncle not indicated distinctly; 4, ventral side of fig. 2 showing downward curvature of sutures of septa ventrally. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90952.

Fig. 5. *Diestoceras curtum* Foerste. Lateral view with ventral outline on left. Popo Agie River, 8 miles west of Lander, Wyoming. From Lander sandstone of Big Horn formation. U. S. National Museum, no. 90937.

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BIG HORN AND RELATED CEPHALOPODS

PLATE XXI

All figures reduced to 0.86 in diameter

Figs. 1, 2. *Charactocerina multicamerata* Foerste. 1, Lateral view showing plications along phragmacone; 2, ventral view. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90955.

Fig. 3. *Metaplectoceras* (?) *landerense* Foerste. Lateral view showing plications. Popo Agie River, 8 miles west of Lander, Wyoming. From the Lander sandstone of the Big Horn formation. U. S. National Museum, no. 90954.

Fig. 4. *Deckeroceras adaense* Foerste. Lateral view exposing siphuncle at base. Lawrence quarry, 7 miles southwest of Ada, Oklahoma. From the Fernvale formation, immediately above the typical Viola formation. Collection of Charles E. Decker.

Fig. 5. *Deckeroceras* sp. Basal part of specimen, including lower end of living chamber and two camerae, sectioned dorsoventrally to show siphuncle. The upper chamber is preserved only partially, and is shifted upward on the left. The entire living chamber is present but is not shown in the figure. Southeast of Nordness, Winneshiek county, Iowa. From the upper part of the Elgin member of the Maquoketa shales. Collected by Harry S. Ladd.

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BIG HORN AND RELATED CEPHALOPODS

PLATE XXII

Figs. 1, 2, 3. *Charactoceras canyonense* Foerste. 1, Ventral view; 2, dorsal view showing narrow but distinct dorsal impressed zone, the roundish lump in the upper right corner being a specimen of *Echinosphaerites*; 3, lateral view with ventral outline on left. Harding quarry, northwest of Canyon City, Colorado. From the basal part of the Fremont formation. U. S. National Museum, no. 90950.

Figs. 4, 5. *Charactoceras canyonense* Foerste. 4, Dorsal view showing dorsal impressed zone; 5, lateral view with ventral side on right. Eight Mile Mountain, north of Parkdale road, north of Canyon City, Colorado. From the basal part of the Fremont formation. U. S. National Museum, no. 90951.

Figs. 6, 7. *Fayettoceras canyonense* Foerste. 6, Lateral view with ventral outline on right; 7, ventral side of specimen with basal part on left, oriented so as to show the transverse bands ornamenting the surface of the shell. Eight Mile Mountain, north of Parkdale road, north of Canyon City, Colorado. Holotype, from the basal part of the Fremont formation. U. S. National Museum, no. 90921. See also plate XII, figs. 1, 2.

Fig. 8. *Diestoceras occidentale* Foerste. Aperture of living chamber viewed from above. Harding quarry, northwest of Canyon City, Colorado. From the basal part of the Fremont formation. U. S. National Museum, no. 90935. See also plate XII, figs. 3, 4.

AUG. F. FOERSTE BIG HORN AND RELATED CEPHALOPODS

NEW LIGHT SOURCES FOR PHOTOGRAPHIC PURPOSES

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The source of light is very important in photography and its value for different purposes depends upon both the intensity and the quality of its light. The standard source, at least with respect to its quality, is the sun and this quality of light is used as the standard for determining the relative speeds of various photographic materials. Needs for artificial sources vary all the way from very intense and very extensive sources for taking commercial moving pictures to a source or sources for taking snapshots and still pictures in the home.

For a long time the photographic studios have been using the regular 500 watt and 200 watt incandescent lamps, or other lamps of about this size, as light sources for illuminating their subjects. Portable lamps have been provided with suitable shades and reflectors for this purpose so that the commercial photographers have found it possible to obtain very good light on their subjects. By the use of light most commercial photographers are able to take pictures of their subjects which are much better looking than the subjects themselves. This is, of course, what is generally wanted. In addition to the regular 500 watt and 200 watt lamps, a special 1500 watt blue bulb photographic lamp has been made available which enables much more light of a high photographic value to be used and, at the same time, the blue bulb absorbs the longer wave length radiation which removes much of the heat from the subject.

Up until the last few years amateurs, for the most part, were obliged to take their pictures when there was sufficient sunlight for the purpose. Therefore, all the preparations were made and

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then the pictures taken inside the house if possible and if not, they either went outside or waited until more sunlight was available. To be sure, some very good pictures were obtained by this method but it was not entirely satisfactory.

In photography three factors determine the character of the negative obtained—meaning by the character of the negative in this case, whether or not it is of the proper density; that is, has it been so exposed that a good picture can be printed from it. The three factors are: the intensity of the light, the character of the optical system and the sensitivity of the photographic plate or film used.

The manufacturers of photographic equipment have made very great advances in the character of their lenses and cameras since amateur photography has become so popular, and during the past few years there has been a very great improvement in the sensitivity of photographic plates and films so that now it is possible, with modern cameras, to take good pictures with a great deal less light than was necessary a few years ago.

Just why is it that the intensity and the character of the radiation are so important and why is it necessary to produce special lamps of high intensity for photographic work? Fundamentally, of course, this can be blamed on the photographic plates or films since they require a definite amount of radiation of a particular quality to fall upon the plate or film in a very definite manner to produce the necessary chemical change to record the impression. While the actual amount of radiation needed is small, the means for getting this necessary amount of radiation to the plate are all very wasteful of light.

Any receiver of radiation can be calibrated with respect to its reaction to radiation of different quality or character. By the quality or the character of the radiation from a source is meant the relative intensity of the light for various wave length intervals. Using wave lengths is an accurate method of designating the different parts of the spectrum corresponding to the rough designation by giving the color in the visible spectrum. The wave length color relation is about as shown in Table I.

No measuring device for radiation has 100% effectiveness for

radiation of all wave lengths excepting a black body receiver. This is not as bad as it seems because means have been found to blacken ordinary receivers so that they will absorb very nearly 100% of the radiation of all wave lengths. The well-known visibility curve of the eye is nothing more than the calibration of the eye as a receiver for radiation of different wave lengths.

The early photographic plates or films were sensitive to the blue part of the visible spectrum and to ultra violet radiation down to wave lengths of about 3000Å or somewhat lower and now methods have been found to make plates sensitive to the longer wave lengths so that it is possible to take a picture of a hot flat iron by means of its own radiation. As compared to the sensitivity in the visible part of the spectrum, such infra-red sensitive plates are very insensitive.

TABLE I

Ultra violet	Shorter than 4000Å
Violet	4000Å to 4500Å
Blue	4500 to 4900
Green	4900 to 5500
Yellow	5500 to 5900
Orange	5900 to 6300
Red	6300 to 7600
Infra-red	Longer than 7600

Various processes have been developed until now we have the orthochromatic plates and films that are sensitive well into the red end of the spectrum and the panchromatic and super sensitive panchromatic that are sensitive far into the red end of the spectrum. All plates, however, are more sensitive to the blue light than to the red light, that is, the same amount of blue radiation falling upon the plates produces a greater effect than the same amount of red radiation. In Figure 1 is shown the spectral distribution of the radiation from the sun and from a tungsten lamp operated at a color temperature[1] of 3500°K. These curves

[1] By the color temperature of a light source is meant the temperature at which it would be necessary to operate a Black Body to obtain light of the same color as that from the source considered. Thus from the color temperature the spectral distribution of light within the visible spectrum can be calculated.

have been plotted on such a scale that they represent the same output of light from these two sources. Curve A shows that the intensity of the blue radiation from the sun is about equal to that of the red radiation. A comparison of these two distributions shows that blue sensitive plates should be relatively more effective

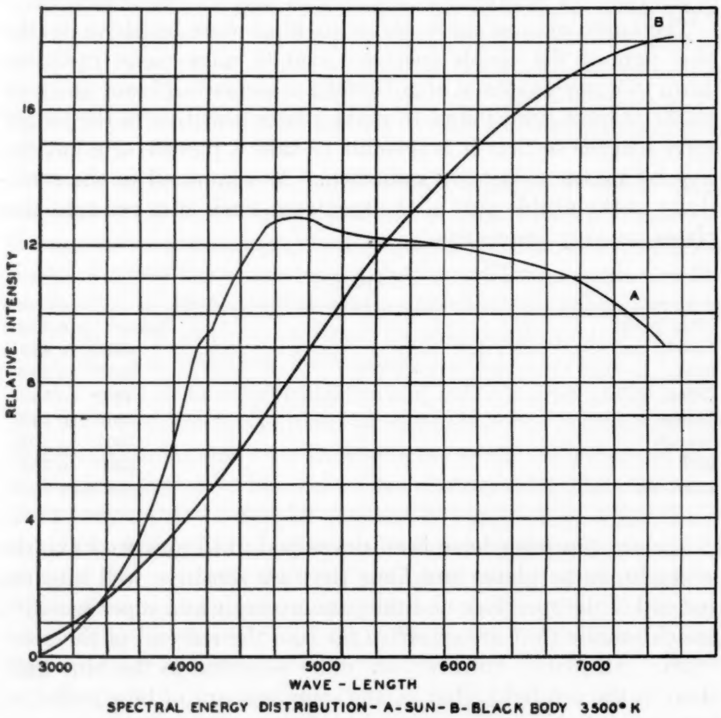

FIG. 1. SPECTRAL DISTRIBUTION OF VISIBLE RADIATION FROM SUN, CURVE A; AND FROM BLACK BODY AT 3500°K, CURVE B

to the same amount of light from the sun than from an artificial source. Curve B shows the great advantage of panchromatic plates for artificial sources since these artificial sources are generally relatively rich in red radiation.

The photoflash lamp, as the name implies, is a lamp intended for

taking flashlight pictures. This requires an intense flash of light which is produced in the lamp by the burning of very thin aluminum foil in the presence of an excess of oxygen. Figure 2 shows a picture of the lamp.

The bulb of the flash lamp contains pure oxygen at a pressure of about 170 mm. of mercury and about 65 mg. of aluminum foil that is about 0.00004 cm. thick and has an area of about 600 square centimeters. To start the foil burning, the filament of the lamp is covered with a primer that ignites when the filament is heated by the electric current. The lamps are now constructed so that they may be flashed on any voltage from that of about two dry cells up to that of the 120 volt lighting circuit.

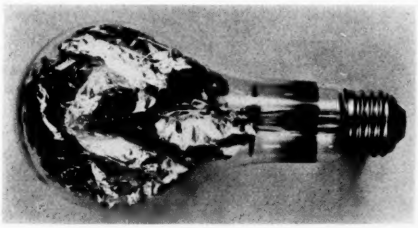

FIG. 2. PHOTOFLASH LAMP

Now that this lamp has been developed and is in fairly good working order, one can write down the specifications for the materials for such a lamp. Since an air tight bulb is used, the product of combustion of the material in the bulbs must be a solid so that the pressure due to the burning of the material inside the lamp will not be increased beyond what the bulb might be expected to stand. If this could not be accomplished, some of the advantages of the photoflash lamps would be lost, that is, the freedom from dirt, noise and whatever danger might result from an explosion in the open. Either the material that is burned or the resulting product must be able to stand a rather high temperature so that it will give off a large amount of light when it is heated by the energy of the reaction, which must be large. It must burn rather quickly without exploding, which

means, in general, that the material should not be in a very finely divided state; probably a thin sheet rather than a fine powder. It must also be a material that at ordinary temperatures will have very little reaction with the oxygen in the bulb. Also the product of combustion should probably be white. Aluminum foil meets practically all of the these requirements in a very satisfactory way.

Before saying anything about the characteristics of the lamp that make it valuable for the purpose for which it was intended, some other interesting characteristics of the lamp will be discussed. As this lamp is made it can be used to demonstrate the law of conservation of mass in chemical reactions. This bulb contains at first aluminum and oxygen and after it is flashed practically all of the aluminum has been burned to aluminum oxide and since this takes place inside of the bulb so that none of the material is lost, the weight of the lamp before and after the flash should be the same if this law holds. To make this test it is best to remove the base since some of the cement that holds the base to the bulb might be lost when the lamp is heated.

The 65 mg. of aluminum foil in the bulbs when burned in an excess of oxygen produces about 1890 watt seconds of energy. If the specific heat of the aluminum foil and the resulting aluminum oxide and certain relations between the oxide and the aluminum foil be considered, a limit for the final temperature can be calculated which is probably considerably higher than the maximum temperature reached. If it be assumed that the reaction takes place so rapidly that no appreciable amount of energy is lost, but that it all goes into raising the temperature of the oxide, a maximum temperature of about 9500°K results. From the maximum intensity of the radiation and projection area of the bulb, a brightness of about 8000 candles per square centimeter is obtained. Some time ago Dr. H. E. Ives[2] published a value of about 9% for the emissivity of aluminum oxide. If the emissivity does not change with the temperature, Dr. Ives' value, together with the brightness of 8000 candles per square centimeter corresponds to a temperature of about 5000°K. As will be shown later,

[2] Ives, H. E. Jour. Franklin Inst. 186, 437 (Oct., 1918).

the distribution of energy in the visible spectrum from the radiation of these lamps corresponds to a temperature of about 3600°K. This is certainly well below the maximum temperature reached.

Oxides behave very peculiarly with respect to their radiation characteristics so it is not safe to extrapolate any one of the characteristics. The above estimates give the limits of temperature reached. Probably the actual maximum temperature is somewhere within this range.

There is another indication that the temperature is very high. If one holds his hand near one of these flash lamps when it is flashed, a very great rush of heat is noticed. If a second lamp is held near (within about a centimeter) of a flashing lamp, this second lamp will also be flashed. Foil from a lamp can be caused to burn in the open air if held very near a flashing lamp. These lamps can not be flashed if held as nearly as possible to a 10 k.w. incandescent lamp, that is, the 10 k.w. lamp does not radiate with sufficient intensity to heat the aluminum foil to the temperature necessary for flashing. Direct sunlight will not flash these lamps but if a lens is used and the solar radiation concentrated on a small spot of the foil, it is possible to flash the lamp. The appearance of foil in the lamp with no oxygen when held near a flashed lamp, together with the above examples, convinced us that the flashing of a second lamp by the flashing lamp was due to the amount of heat radiated by the lamp.

About as soon as this lamp was far enough along in development to make it possible, a study was made of methods for measuring its characteristics. It seemed necessary to measure the total quantity of light given off by the lamp in lumen seconds, and the maximum intensity of the light expressed in lumens as well as some of the time characteristics such as the length of time between closing the circuit that started the current through the filament and the beginning of the flash, the time to the maximum of the flash as well as the total duration of the flash.

No better method of measuring these different characteristics seemed available at that time than exposing—through a slit—a falling photographic plate to the radiation from a flashing lamp. This should leave on the photographic plate a trace with the

density at different points proportional to the intensity of the light flash at the time that part of the plate was exposed. Then, if proper precautions were taken and a proper calibration made, these characteristics could all be obtained from measurements on such traces. A very crude wooden apparatus was made so that a 5″ x 10″ spectrum photographic plate could be allowed to fall in front of a slit with an arrangement so that when the lower edge of the plate reached the slit, electric contact was made which closed the lamp circuit.

This apparatus, which was made so that the plate would be as nearly freely falling as possible, was ready on Friday morning and a number of the lamps were obtained and the tests started. It was planned to have a time scale impressed upon the plate but at first this was not ready. That afternoon several good traces were obtained from the photoflash lamps. To get a measure of the maximum intensity of the light that made these traces, the falling plate was exposed to the radiation of an ordinary 500 watt incandescent lamp, and by trial and error the relative distance found for the 500 watt lamp and the photoflash lamp so that the density of the trace at the maximum for the photoflash lamp was equal to the density of the trace for the 500 watt lamp.

It is generally known that around an engineering laboratory reports are a necessity. It was thought that it would be a good idea to get the report in on time, so by a special effort the report was sent to headquarters Saturday morning. In the report figures were given on the total quantity of light as estimated from the density and length of the trace, the maximum intensity, the total duration of the flash and the time between the turning on of the current and the maximum of the flash. The time characteristics had to be obtained by calculation assuming the plate to be freely falling. With the apparatus as used, it was possible to get test traces of only 4 lamps on each plate. Monday morning one of the engineers working on this lamp came down and said they had about 200 lamps made up with various specifications that they would like us to test and report on just as we had the few on Saturday morning! Counting 4 lamps per plate, 200 lamps would require 50 plates!

This showed right away that something had to be done to speed up the work and also to make more accurate results possible. This meant that a new piece of apparatus was necessary in a hurry so the carpenter constructed a device similar to the other one so that by using a 10″ x 12″ falling photographic plate, traces of 12 lamps could be recorded on each plate. A time scale was put on the plate by exposing the plate to the image of a small portion of the filament of a carbon lamp through a narrow slit. The lamp was heated by 60 cycles alternating current and a small magnet held near the lamp, so that the filament was caused to vibrate along the slit 60 times per second which gives a trace on the falling plate that enables quite accurate measurements to be made of the relation between time and distance along the trace. This method is not new but is one that was described some time ago. Several thousand lamps were tested with this falling plate flashometer but it was not entirely satisfactory because the motion of the plate was not uniform nor would the plate fall in such a manner that each trace occupied the same time. This meant that a calibration had to be made for each single trace for accurate results. It did have some redeeming features, principally its simplicity and the ease in which it could be set up and operated.

But again the amount of work required grew to such an extent that better facilities had to be provided. This time a constant speed flashometer was made which consisted of a drum rotated at constant speed by a synchronous motor and having attached to the outside of the drum a photographic film with arrangements for exposing different portions of this film to the radiation from the flashed lamp. An arrangement was provided so the various constant speeds could be obtained. This cylinder was made of such a diameter and as used (for the most part) rotated at such a speed that $\frac{1}{20}$ of an inch represented very accurately $\frac{1}{1000}$ of a second. With this apparatus it was possible on a 10″ x 12″ film to record the trace of 25 lamps. This, together with the ease with which distance on the film can be converted into time, makes this latter piece of apparatus very satisfactory for our work. A picture of this rotating flashometer is shown in Fig. 3

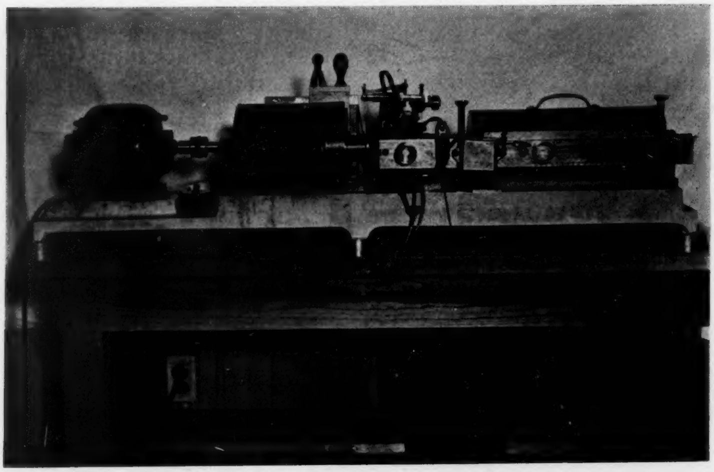

FIG. 3. ROTATING FLASHOMETER

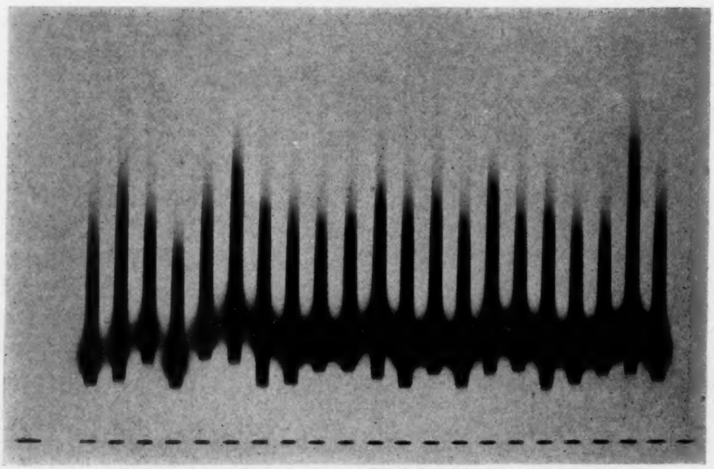

FIG. 4. PLATE OBTAINED WITH ROTATING FLASHOMETER

Dotted line shows point where current was turned on. Time scale on left, period 1/60 second.

and a copy of a film showing traces of photoflash lamps is shown in Fig. 4.

With this apparatus it is necessary to have some means of opening the shutter and of turning the current on through the filament at a definite position of the film. Also, after the shutter is opened and the filament current turned on and the lamp flashed, the shutter must close and the circuit making mechanism

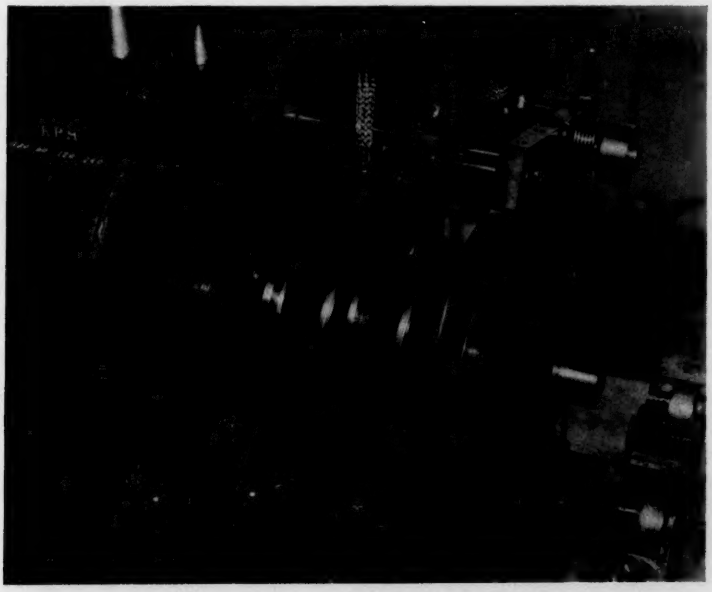

FIG. 5. CONTACT MECHANISM OF ROTATING FLASHOMETER

must not repeat as the drum is rotated until one is ready for the next lamp. This was very easily done by copying from the contact mechanism of an oscillograph. A hard rubber cylinder about 3 inches in diameter and about two inches long was made with about three "v" threads per inch and with one of the center "v" threads made of metal. To get a trace of the radiation from a lamp, with the drum rotating, the two insulated copper contact brushes, shown in Fig. 5, are dropped from their initial position

on to the thread of the insulated part of the cylinder in front of the metal contact; thus the contact is not made until the threads on the rotating commutator move the contact brush to the metal part, and then after one rotation of this rubber cylinder attached to the shaft of the rotating camera, the two brushes pass beyond the metal portion and break the contact, which can not be made again until the apparatus is re-set. A cam at the end of the cylinder raises the contact holder so that it is held up by the latch and then the spring pulls it back to the initial position. The first contact brush closes the circuit that opens the shutter in front of the particular part of the camera being used and then a short time afterwards (about $\frac{1}{10}$ turn) the second contact brush closes the lamp circuit. This is a very good method of making a commutator that must not repeat.

Determining the intensity of the light from the photoflash lamp by a measurement of the density of the trace on the film was entirely too slow, so something else had to be done. It was found by trial that the photoelectric tube used in the regular photometric measurement of incandescent lamps with a particular green glass screen in front of it connected to a very sensitive galvanometer made quite a satisfactory photometer for these flash lamps. The period of the galvanometer used is about 6 seconds and the period of the photoflash lamps a small fraction of a second, so that the entire rush of current is over before the galvanometer moves appreciably out of its zero position. Thus, the conditions are fulfilled for an accurate ballistic measurement. Exposing the photoelectric tube to the light from the flash lamp gave to the galvanometer coil a ballistic throw of from 50 to 200 centimeters deflection depending upon the lamp and its distance from the photo tube. With a deflection of this size, a fair degree of accuracy can be obtained for the total quantity of light radiated by the photoflash lamp providing a proper calibration has been made.

This photoelectric tube is calibrated by exposing it for a very short time, by means of a pendulum device, to the light from a very high wattage tungsten lamp. Since the radiation from a photoflash lamp is so intense, it is necessary to bring the high

wattage tungsten lamp very near the photoelectric tube photometer and also to expose it for a longer time than the period of the flash of the lamp. A period of 0.14 of a second was used. Thus, the total quantity of light given off from the lamp can be measured.

The maximum intensity of the photoflash lamp is an important characteristic of the lamp and is one that at times it is necessary to measure. This can be obtained from the time traces on a photographic plate, but again this requires too much time and effort. The current from a photoelectric tube exposed to the light from a photoflash lamp follows very closely the variation in the intensity of the light falling upon it. Thus, to measure the light variation of the lamp it is only necessary to measure the current from the photoelectric cell as a function of the time. This time variation of the current can be measured with a very sensitive oscillograph, but unfortunately we did not have such an instrument so some other method had to be devised. The method finally adopted is the one that is used when it is desired to make an electric circuit remember some particular condition. The current from the photo tube was passed through a high resistance and the varying fall of potential over the resistance made to charge a condenser. If now some way could be found to make the condenser keep the maximum charge the problem would be solved, since the maximum charge is proportional to the maximum current, which is again proportional to the maximum light intensity.

If an electric valve were put in the condenser circuit so that the charge could flow on to the condenser but not off, the maximum charge would remain on the condenser. The values of the capacity of the condenser and the resistance in the circuit must be kept at such a value that the time constant will not be too large or the maximum of the charge will not have time to reach the condenser. Several standard valves were tried but they did not work for this purpose, so Dr. Saul Dushman, of the General Electric Research Laboratory in Schenectady, made us some special kenetrons which worked very well. Since this apparatus is to measure the maximum intensity of the light falling upon the

photo tube, it can be calibrated by exposing it to the radiation of any source of known high intensity.

Four photoflash lamps are at present manufactured; the #10 lamp which is in a small bulb about the size of the 40 watt lamp, the #20 lamp which is in a bulb about the same size as the 100 watt lamp, a much larger lamp, #75 which has a bulb about the same size as the 300 watt incandescent lamp and a flash lamp in a blue bulb the size of the #20 lamp. This blue bulb is used to eliminate a very great amount of the long wave length visible radiation without greatly reducing the blue or ultra violet radia-

TABLE II

Characteristics of photoflash lamps

LAMP	WEIGHT OF Al (MG.)	BULB DIAMETER (CM.)	TIME FROM CLOSE OF CIRCUIT TO		TOTAL LIGHT OUTPUT (LUMEN SECONDS)	MAXIMUM INTENSITY (MILLION LUMENS)
			Start of flash (second)	End of flash (second)		
Exp.	3	0.6	0.004	0.020	500	0.03
Exp.	20	3.8	0.015	0.035	5,970	1.1
#5	20	4.7	0.026	0.060	8,000	1.0
#10	40	6.0	0.010	0.074	24,600	2.8
#20*	80	7.3	0.010	0.074	6,200	1.0
#20	80	7.3	0.010	0.074	53,000	6.1
#75	320	11.1	0.020	0.160	195,000	8.8
Exp.	440	12.7	0.020	0.135	221,000	
Exp.	1,000	20.0	0.015	0.087	688,000	46.0
Exp.	3,300	31.0	0.022	0.147	1,900,000	55.0

* Blue bulb.

tion which is the more effective, photographically. The characteristics of many different photoflash lamps ranging in size of bulbs from about 1/4 inch in diameter up to large ones with bulbs (S-96) about one foot in diameter have been studied. Some of the characteristics of these lamps are shown in Table II.

There are two other characteristics of the lamp that it is desirable to know—one is the distribution in the spectrum and the other is the distribution of the light as a function of the time from the turning on of the lamp. The time distribution of the light from the lamp was measured by exposing a film on the

rotating drum, properly calibrated to the radiation from the lamps and then determining the light intensity from the density of the trace. The time intensity curves for three different sizes of photoflash lamps are shown in Fig. 6.

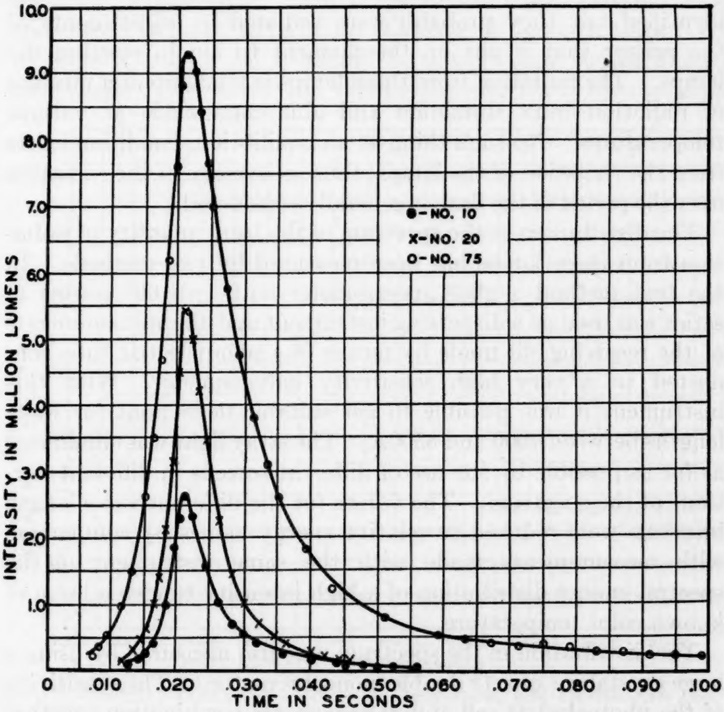

Fig. 6. Time Intensity Curves for Three Different Types of Photoflash Lamps

The curve for the #75 lamp has been shifted 0.021 second toward origin

The spectrum of the radiation from a photoflash lamp shows a few bright lines, a number of bands and a continuous background. The ultraviolet radiation, as shown by a spectrum taken with a crystalline quartz spectrograph by flashing four or five lamps in front of the slit for a single spectrogram, extends to

about 3000Å, but was not very intense and there were no lines in the ultraviolet portion of the spectrum strong enough to show through the continuous background. About forty of these bands and lines have been measured and identified as belonging to aluminum and to aluminum oxide. Several lines were not identified but they probably were radiated by constituents of the primer that is put on the filament to aid in starting the lamps. The radiation from these lamps is made up of a mixture of radiation from aluminum and aluminum oxide at various temperatures. No such thing as an equilibrium condition exists from the radiation of the lamps; thus an average of the radiation over the period of the flash is generally considered.

The distribution in the spectrum of the total quantity of radiation from these lamps has been measured by two methods. In the first method a glass spectrometer with two 60° prisms in series was used as a dispersing instrument and the measurements at the receiving slit made by means of a photoelectric tube connected to a very high sensitivity galvanometer. With this instrument it was possible to get suitable deflections for wave lengths between 4000 and 8500Å. The stray light was eliminated as far as possible by the use of different screens in different portions of the spectrum. The values for the different wave length intervals were reduced to relative energy values by comparison with measurements made with the same instrument on the spectral energy distribution of a high intensity tungsten lamp of known color temperature.

The distribution in the spectrum was also measured by using a large crystalline quartz double monochromator.[3] The sensitivity of the photoelectric cell and galvanometer combination together with large light gathering power of the instrument enabled measurements to be made from about 3000Å to about 12,000Å. The transmission of the instrument and the spectral sensitivity of the photoelectric cell were measured by Dr. Barnes of this laboratory so that the galvanometer deflections could be expressed directly in relative energy values. A very good agreement was obtained for the energy distribution by these two methods as

[3] Review of Scientific Instruments, 4, 281 (May, 1933).

can be seen from the plotted data in the curve of Fig. 7. The distribution for the range measured agrees very well with data published by Ives[4] and his co-workers on the spectral distribution of energy in the spectrum of aluminum oxide when heated by means of a gas flame. The shape of the curve in the visible spectrum was found to be about the same as that of a black body at 3500°K. This value should be lower than the estimated temperature since this is the average distribution of the radiation

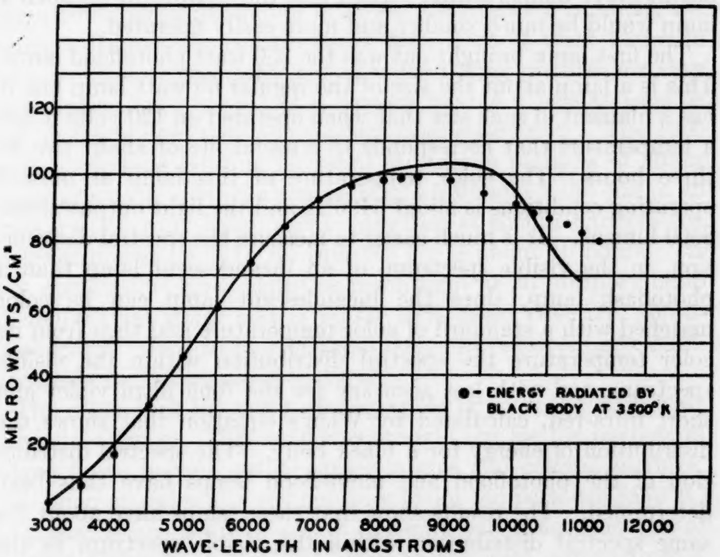

FIG. 7. SPECTRAL DISTRIBUTION OF RADIATION FROM #20 PHOTOFLASH LAMP

from the lamp. This is made up of some low temperature radiation which will, of course, change the distribution to a seemingly lower value than that corresponding to the maximum temperature. These relative values were reduced to absolute values by making the area under the curve equal to the total output of the lamp.

The photoflash lamp suggested to one of our engineers the

[4] *loc. cit.*

idea that it would be desirable to have an incandescent lamp of high intensity for taking still pictures in the home. This idea resulted in the development of two photoflood lamps and a movieflood lamp. All things considered, it seemed best to make these lamps for high temperature operating, which means short life, because the light output of the lamp increases very rapidly as the life is reduced, and also because the light from a lamp filament at high temperatures is more effective photographically than from one at lower temperatures. Then too, the equipment for such a lamp would be much smaller and more easily operated.

The first lamp brought out was the 250 watt photoflood lamp. This is a lamp about the size of the regular 60 watt lamp but it has a filament of such size that when operated on 120 volts it has a temperature that corresponds to a useful life of about two to three hours. The color temperature of this lamp at normal operating conditions is about 3490°K and the light output about 8600 lumens. It is much easier to measure the spectral distribution, in the visible spectrum, of an incandescent lamp than a photoflash lamp, since the incandescent lamp can be color matched with a standard of color temperature and then from its color temperature the spectral distribution within the visible spectrum, and with less accuracy for the long ultra violet and short infra-red, calculated by Wien's equation that shows the distribution of energy for a black body. The spectral distribution of the photoflood and movieflood lamps have thus been determined. The results show that these lamps have about the same spectral distribution within the visible spectrum as the #20 photoflash lamp. The difference of about 100° in color temperature at 3500°K between the #20 photoflash lamp and the 1000 watt photoflood lamp means that if the intensity of the radiation of these two sources were made equal in the red end of the spectrum ($\lambda = 6650$Å) the photoflash lamp would be about 8% more intense in the blue part ($\lambda = 4500$Å). The light output of this 250 watt photoflood lamp is about twice that of an ordinary 250 watt lamp and due to its higher color temperature, the photographic effectiveness of the light from this lamp is about 25%

more than that from the ordinary 250 watt lamp. Thus, we have a relative photographic effectiveness of about $2\frac{1}{2}$ between this lamp and a regular 250 watt lamp.

Two to three hours life may seem short, but if the lamp is operated at about one-half voltage for the time required to focus the camera and then turned on at 120 volts for the period of actually taking the picture, a great many pictures can be taken during the useful life of the lamp. A very convenient way to use these lamps is to have them so connected that they can be operated either in parallel or in series. If operated in series, the lamps will have about 1000 hours life. Two of these lamps in proper reflectors give sufficient light for taking pictures for very short exposures ($\frac{1}{25}$ sec.), if a camera having a lens at least as fast as f/6 is used with the modern high speed film. The 1000 watt photoflood lamp is intended for taking pictures of either larger groups or colored pictures, is in a bulb about the size of an ordinary 250 watt lamp, and is operated at such a temperature (color temperature 3410°K) that the life is about 10 hours. As it is operated, it gives about as much light as an ordinary lamp of about 1600 watts and is about 20% more effective photographically. Two to four of these lamps in reflectors give sufficient light for taking group pictures.

The other high intensity photographic lamp is the 2000 watt movieflood lamp. This lamp was brought out for the purpose of taking home movies, rather larger groups and colored pictures. This lamp operates at a temperature (color temperature 3430°K) such that it has a life of about 15 hours and a light output of 67,000 lumens which is about equal to the light output from a 3300 watt lamp if operated at such a temperature as to have 1000 hours life. The photographic effectiveness is also increased about 25% due to the increase in temperature over the 1000 hours life.

In addition to the 3 photoflood lamps, we are making the 5 and 10 kilowatt lamps that are used in the moving picture studies. These lamps are constructed so that they have a life of from 50 to 100 hours, which means that they operate at a temperature

around 3350°K. Their filaments, all in one plane, are constructed to operate in reflectors so that by their use a very great amount of light can be thrown upon any scene that is being set up for taking moving pictures.

A list of the photographic lamps we are making with some of their characteristics are given in Table III. This list does not include the large lamps (3 to 10 kilowatt) used in the moving picture studio. The table contains no direct data on the relative photographic value of these different sources. However, with

TABLE III

Characteristics of photographic lamps

LAMP	DIAMETER OF BULB (CM.)	TIME FROM TURNING ON CURRENT TO START OF FLASH (SECONDS)	DURATION OF FLASH (SECOND)	TOTAL LIGHT OUTPUT (LUMEN SECONDS)	MAXIMUM INTENSITY (MILLION LUMENS)	RELATIVE PHOTOGRAPHIC EFFECTIVENESS
#10	6.0	0.010	0.050	16,000	1.4	0.4
#20	7.3	0.009	0.060	40,000	3.1	1.0
#75	10.2	0.017	0.100	169,000	10.2	4.2
		WATTS	COLOR TEMPERATURE			
#1 photoflood		250	3490°K	8,600		0.023*
#4		1,000	3410	32,000		0.08*
Movieflood		2,000	3430	67,000		0.15*
5 K.W. lamp		5,000	3420	145,000		3.4*

* Time 1/10 second.

the exception of the photographic blue lamp, one would not expect wide variations in the photographic effectiveness if they were all reduced to the same light output, since the color temperature of the lamps listed does not differ markedly. However, for some plates the range of color temperature covered by these lamps makes a difference in the effectiveness.

Thus far nothing has been said about the number of lamps of the different kinds that must be used to obtain good pictures under various conditions. Our engineers have used these photographic lamps for taking pictures under various conditions and

for various sorts of subjects, groups and scenes, and from such experiences have worked out an estimate of the number of lamps necessary for groups and scenes of different sizes. If a camera that has a lens opening of f/16 is used in a room with medium colored walls and ceiling, and a normal panchromatic film is employed, one #20 photoflash lamp in a reflector will give sufficient light for about 200 square feet of floor space. Since the #10 photoflash lamp gives about one-half as much light as the #20 lamp, this lamp in a reflector will give sufficient light to cover about 100 square feet of area. The #75 lamp, of course, would give enough light for a considerably larger area.

TABLE IV

Table of exposures for taking pictures using present day high speed panchromatic films

DISTANCE TO SUBJECT	LAMP IN REFLECTOR	DIAPHRAGM OPENING	TIME (SECONDS)
4 feet	#1 photoflood	f/4.5	0.1
6 feet	#1 photoflood	f/4.5	0.5
6 feet	#4 photoflood	f/4.5	0.1
8 feet	#10 photoflash	f/16	
12 feet	#20 photoflash	f/16	
Group	#20 photoflash	f/16	200 sq. ft. floor area
Group	#75 photoflash	f/16	800 sq. ft. floor area

Either the #10 or the #20 photoflash lamp will give sufficient light for taking snap-shots of small groups or of individuals with any of the moderately fast panchromatic plates and with a lens at least as fast as f/16. The photoflood lamps give considerably less maximum intensity than the photoflash lamp so that with any time of the order of one-tenth or one-half of a second and a lens opening of f/16, it would require more than one of the #1 photoflood lamps to give enough light to obtain a good picture. However, one #1 photoflood lamp in a reflector, used with a camera having a lens at least as fast as f/4.5 and with present day fast panchromatic film, will give sufficient light to allow snap-shots to be taken in one-tenth of a second if the light is only about 4 feet from the subject.

Table IV gives some estimates that have been calculated from the work of our engineers in taking pictures with these various photographic sources. This table, as is indicated, presupposes the use of high speed panchromatic films. Of course, better effects can be obtained if more than one lamp is used because by such use shades and shadows can be controlled but here is where a mere physicist leaves off and art enters.

It is a pleasure to thank Miss Easley and Mr. Watson of this laboratory for assistance in obtaining much of the data presented in this paper.

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